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Missouri Geological Survey.
  Biennial report.

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OLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

1889/90

15th BIENNIAL REPORT

OF THE

STATE GEOLOGIST

TRANSMITTED BY THE

BUREAU OF GEOLOGY AND MINES

TO THE

36TH GENERAL ASSEMBLY

JEFFERSON CITY, MO.:
TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS.
1891.

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

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JEFFERSON CITY, MO.:
TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS.
1891.

On motion, 1,000 copies ordered printed, January 22, 1891.

Mr. Davis, of Henry county, offered the following resolution: *Resolved*, That 2,000 copies of the biennial report of the State Geologist be printed in the form prescribed by law—1,000 of said copies for the appendix to the House journal and the remainder for the office of the State Geologist for distribution. Which was read and adopted.

A. S. SMITH, Chief Clerk.

LETTER OF TRANSMITTAL.

January 22, 1891.

To the Thirty-sixth General Assembly of the State of Missouri:

GENTLEMEN—The Board of Managers of the Bureau of Geology and Mines, appointed under an act approved May 23, 1889, was organized August 28, 1889, and, on the following day, Arthur Winslow was elected State Geologist, and entered on the discharge of his duties on the 20th of September, 1889. The progress of the work is set forth in the report of the Geologist, which is forwarded herewith through the House. The Board has endeavored to use the money at its disposal to the best advantage, and is of the opinion that the State is more than amply repaid for the expenditure made by the additional knowledge that has been acquired, and the valuable information that has been disseminated concerning the mineral wealth and resources of Missouri. The monthly reports of the Geologist have been of benefit to the public, and the bulletins issued have presented, in practical form, the results of the Survey, and have added materially to the literature of Missouri geology. In our opinion the Survey should be continued in the line begun, and to enable the accomplishment of that end an appropriation much larger than that of 1889 is desirable, if not necessary. Bulletins Nos. 2 and 3 are now in print and will be ready for distribution in a few days. We desire to call your especial attention to the interesting report of the Geologist, which gives a history of Missouri geology from its beginning, and states, in an impressive manner, the advisability of a continuation of the present survey, besides showing, in detail, the progress that has been made since the organization of this Board.

Respectfully,
DAVID R. FRANCIS,
Governor and ex officio President of the Board of Managers
of the Bureau of Geology and Mines: For the Board.

PREFATORY LETTER.

JEFFERSON CITY, Dec. 31, 1890.

To the President, Governor David R. Francis, and the Members of the Board of Managers of the Bureau of Geology and Mines:

GENTLEMEN—I have the honor to submit to you, herewith, my report of the operations of the Geological Survey of the State since the beginning of work in October, 1889, to the present date.

As the present work is practically a continuation of operations begun by earlier Surveys, I have introduced this report by an historical sketch describing the origin, the progress and the results reached by these Surveys, so that the foundation upon which the present work stands may be clearly known, and so that the reasons for the existing plans of work may be appreciated.

Following this I have undertaken to describe the organization of the present Survey, giving an outline of the general plan of work and the reasons for adopting it.

Succeeding this is a statement of the results which have been reached by the Survey during this year's work, after which I have submitted a classified statement of the expenditures to date. The last part of the report is devoted to a consideration of the needs for the future.

That the results of this, the first year's work, may meet with your approval, and that they may prove of true benefit to the State, is my earnest hope. Toward this end I have directed my best efforts. In this work, however, I have been cheerfully sustained by other members of the Survey, and recognition for this is due them here. Such success as may have resulted is due, in large part, to their co-operation. Coming to the Survey variously prepared and with variable appreciation of the character of the work ahead, they have, as a body, applied themselves with zeal to the accomplishment of immediate ends; they have endured the exposures and the hardships without complaint, and have displayed ability and talent in the execution of the work.

Further, the Survey owes a debt of gratitude to those citizens of the State who have advanced the work, either by extension of hospitality, by furnishing information or by guidance in the field. Such assistance not only hastens the progress of the work, but, when accompanied by a cordial exhibition of interest, adds zest and a sense of recognition which is always inspiring.

Finally, Mr. President, I owe to you, with whom I have been in most frequent intercourse, an expression of gratitude for the attention you have given to all affairs of the Survey concerning which I have consulted you, for your valuable advice in relation to matters of administration, and for the confidence you have exhibited in my management.

To other members of the Board I am further indebted for much assistance in advancing the work, and for hospitalities extended to myself and others of the Survey corps.

Very respectfully submitted,

ARTHUR WINSLOW,
State geologist.

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BIENNIAL REPORT OF THE STATE GEOLOGIST
FOR THE YEARS 1889 AND 1890

HISTORICAL SKETCH.

OPERATIONS PRECEDING THE FIRST GEOLOGICAL SURVEY.

The geology of the State of Missouri has been a subject of study for comparatively few years. But, though this is true with reference to the general geology of the State, or so far as any systematic investigation of its mineral deposits is concerned, yet the existence of such mineral deposits has been known for a long time. From early in the eighteenth century the lead deposits of the State (then a part of the colony of Louisiana) attracted attention. The operations of Sieur de Lochon on the Meramec in 1719 were among the earliest. In 1720, the Mine LaMotte was worked under Governor De LaMotte, the first governor under the Crusat patent. The immigration, started through John Law, brought many miners to the State who continued the development of the lead deposits. The precious metals were generally the objects of search in these early mining ventures; but, at the same time, a large amount of lead was produced, though mostly from surface diggings.

About the time of the transfer of Upper Louisiana to the United States, in 1804, we find a communication to Congress on the lead mines of the region, by Capt. Amos Stoddard,* of the United States Army, the officer assigned to take possession of the District. Succeeding this there are a number of communications and reports to Congress, by Lieut.-Col. Bomford, of the United States Army, and others, relating to the lead mines and salt springs. These were, in part, the results of private or incidental observation, and, in part, the result of special inquiry for the purpose of land classification. They can hardly be classed as products of professional explorations.[1]

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* See American State Papers, 2nd Session, 8th Congress. No 103. Vol. 1, pp. 188-191. Also Appendix B., p. 686, Report of the Geological Survey of Missouri for 1873-4.

About the same, and in the immediately succeeding years, expeditions and explorations of a more pretentious nature were planned and executed, generally under military control. Those including Missouri as part of their territory are the Lewis and Clarke expedition, from 1804 to 1806[2], the Pike expedition, from 1805 to 1807[3]; the Long expedition in 1819.[4] The reports of these expeditions contain matter relating to the geology of Missouri; but it is only such matter as could be gathered from observations along a limited strip of country tributary to the line of travel, and from cursory observations at that.

In 1834, Mr. G. W. Featherstonhaugh made an examination of the elevated country between the Missouri and Red rivers, under the auspices of the war department[5]: His report refers to explorations in the Ozark mountains, and he writes of the iron ores and of the lead mines of Missouri, referring especially to the latter, and deploring the manner in which the latter are worked.

In Owen's report of a Geological Exploration of a part of Iowa, Wisconsin and Illinois in 1839,[6] reference is made to the rocks of Missouri and a classification of them is proposed. Later, in his report of 1851 of a Geological Survey of Wisconsin, Iowa and Minnesota,[7] is included a description of northern Missouri, with a special reference to the coal fields.[1]

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[1] See reference to "American State Papers, Miscellaneous Documents of the United States Congress," pp. 46 and 48, Bibliography of Missouri, Bulletin No. 2, Geological Survey of Missouri, 1890.

[2] Travels to the Source of the Missouri River and across the American Continent to the Pacific Ocean, performed by order of the Government of the United States in the years 1804, 1805 and 1806. By Captains Lewis and Clarke: published from the official report, and illustrated by a map of the route and other maps. London: Printed for Longman, Hurst, Rees, Orme & Brown, Paternoster Row. 1814. Quarto.

[3] Exploratory Travels through the Western Territories of North America: Comprising a Voyage from St. Louis, on the Mississippi, to the Source of that river, and a Journey through the Interior of Louisiana, and North-eastern provinces of New Spain. Performed in the years 1805, 1806 and 1807, by order of the Government of the United States. By Zebulon Montgomery Pike, Major 6th Regt., United States Infantry London: Printed for Longman, Hurst, Rees, Orme and Brown. Paternoster Row, 1811. 4, 436 pp.

[4] Account of an expedition from Pittsburg to the Rocky Mountains, performed in the years 1819 and 1820, under command of Major S. H. Long. Philadelphia 1823. The Atlas accompanying it was issued in 1822.

[5] Geological report of the examination made in 1834 of the Elevated Country between the Missouri and Red Rivers. By G. W. Featherstonhaugh, U. S. Geologist. Washington, 1835. 97 pp.

[6] See Message President of the United States concerning the Mineral lands of the United States. 1st Session, 26th Congress, H. R Ex. Doc. No. 239, pp. 9-115

Also republication with slight revision in 1884, in Senate Doc. No. 407 of 28th Congress

[7] Description of the Carboniferous Rocks of Iowa, including that of a Coal field west of the Mississippi, lying partly in Iowa and partly in Missouri, etc. Report of a Geological Survey of Wisconsin, Iowa and Minnesota; and incidentally of a portion of Nebraska Territory. By David Dale Owen. Phil. 1852. 4to.

The explorations and researches thus far referred to have, however, all been made under the auspices of the General Government, or were the results of individual enterprise. About the earliest record which we have of official action on the part of the State in the direction of a geological survey is in the message of Governor Lilburn W. Boggs, to the 10th General Assembly, in 1833. In this he recommends an appropriation for a geological survey as a part of a general system of internal improvement. He refers to the activity of other States in this direction, and he cites the advantages and benefits to be derived from such a survey.

Apparently as a product of the spirit prompting this recommendation, the surveys of the Meramec, the Salt, the North Grande and the Osage rivers were promptly started under a Board of Internal Improvements, and a geological examination of the Osage river was made under Dr. H. King.[2]

This report is referred to by Governor Boggs in his message to the ensuing Legislature, in the year 1840, in which he speaks of the coal, lead and iron of the Osage river country.[3]

After this, the matter of further investigation by the State seems to have fallen into neglect for several years. But, in October, 1846, a convention was held in Springfield in the interest of internal improvements. At this convention a memorial was framed to the General Assembly[4] in which especial stress is laid upon the value of the development of the mineral deposits of the State. In the message of Gov. John C. Edwards to the General Assembly in the same year[5] the subject of a geological survey of the State is again recommended for consideration. The matter was referred to the Committee on Internal Improvement, of which DeWitt C. Ballou was Chairman. In a report of eight pages[6] this committee strongly advises the inauguration of such an undertaking, and cites the advantages to be derived in detail. No immediate action seems to have followed this, however, and, at the next session of the General Assemby in 1848, a memorial of 13 pages was presented from the Historical and Philosophical Society of Missouri,[1] again inviting thé attention of the Legislature to the matter. This memorial refers to the value of the results of such work in guiding members of the State Government in directing works of internal improvement; it refers to the various mineral deposits of the State, and explains why and how such a survey would result in benefit.

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[1] An interesting fact, historical, in this connection, is Owen's assignment of the Upper Coal Measure Limestones of Northwest Missouri to the Lower Carboniferous formation, a determination disproved early in the progress of the First Geological Survey of the State, under Swallow.

[2] See report of the Board of Internal Improvements to the General Assembly of Missouri, pp. 485-525. Report of a Geological Reconnoissance of that part of the State of Missouri adjacent to the Osage river, made to William H. Morell, Chief Engineer of the State, by order of the Board of Internal Improvement, by Henry King, M. D., Geologist, President of the Western Academy of Natural Sciences, etc., etc.; pp. 506-525. Senate Journal, Appendix, 1st Session, 11th General Assembly, 1840; pp. 458 525.

[3] See message of Gov. Lilburn W. Boggs, Nov. 17, 1840. 15 pp. Senate Journal, 1st Session, 11th General Assembly, 1840, pp. 15-29. House Journal, same. pp. 12-26.

[4] See Appendix House Journal, 1st Session, 14th General Assembly, 1846, pp. 245-249.

[5] See Senate Journal, 1st Session, 14th General Assembly, 1846, pp. 25-35. Also House Journal, same year, pp 17-28.

[6] See House Journal, 1st Session, 14th General Assembly, 1846, pp. 250-257.

The immediate effect of this memorial was another memorial from this Legislature to Congress,[2] urging that the National Government have a geological survey of the State made. Nothing seems, however, to have resulted from this memorial, and, in the following year [1850], Governor Austin A. King, in his message to the 16th General Assembly, again urges the importance of attending to these matters. He advises thorough work, but is of the opinion that the General Government should contribute to the expense of this work, inasmuch as two-thirds of the land of the State was Government property. He recommends that the memorial of the last Legislature be again pressed upon the attention of Congress. Again nothing immediate seems to have been done, but the interests involved were too important for the work to be much longer neglected. Previous agitation of the subject had educated the people to an appreciation of the need of such work. Papers were published advocating it,[3] and, during the session of the Legislature, an act creating the First Geological Survey of the State was passed and approved Feb. 24, 1853.

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[1] See Senate Journal, 1st Session, 10th General Assembly, 1838, pp. 13-28.

[2] Memorial of the Legislature of Missouri, relative to a General Survey of that State. Feb. 29, 1849. 30th Congress, 2d Session, House of Reps., Miscellaneous, No. 58, 3 pp.

[3] See Western Journal and Civilian. Vol. III, pages 12 and 76, Vol. VIII, page 228, Vol. IX, page 319.

THE FIRST GEOLOGICAL SURVEY OF MISSOURI.

The act creating the first geological survey of Missouri reads as follows:

AN ACT TO PROVIDE FOR A GEOLOGICAL AND MINERALOGICAL SURVEY OF THE STATE.

Be it enacted by the General Assembly of the State of Missouri, as follows:

1. The governor of this state is hereby authorized and required, as soon as may be after the passage of this act, to appoint a state geologist, who shall be a person of competent scientific and practical knowledge of the sciences of geology and mineralogy; and the said state geologist shall, by and with the consent of the Governor, appoint any number of suitable persons, not exceeding four, to assist him in the discharge of his duties, who shall be skillful analytical and experimental chemists; and may appoint such other subordinate assistants as he may deem necessary.

2. It shall be the duty of the said state geologist and his said principal assistants, as soon as may be practicable after their appointment, to commence and carry on, with as much expedition and dispatch as may be consistent with minuteness and accuracy, a thorough geological and mineralogical survey of this state, with a view to determine the order, succession, arrangement, relative position, dip or inclination, and comparative magnitude of the several strata, or geological formations, within this state; and to discover and examine all beds or deposits of ore, coal, marls and such other mineral substances and mineral waters as may be useful and valuable, and to perform such other duties as may be necessary to make a full and complete geological and mineralogical survey of the state.

3. It shall be the duty of the said assistants to make full and complete examinations, assays and analyses of all such rocks, ores, soils or other substances as may be submitted to them by the state geologist for the purpose, and to furnish him with a detailed and complete account of the results so obtained.

4. It shall be the duty of the said geologist, on or before the first day of December in each and every year, during the time necessarily occupied by said survey, to make an annual report of the progress of said survey, accompanied with such maps, drawings and specimens as may be necessary and proper to exemplify and elucidate the same, to the secretary of state, who shall lay such report or reports before the legislature.

5. It shall be the duty of the said state geologist to cause to be represented on the map of the state, by colors and other appropriate means, the various areas occupied by the different geological formations in the state, and to mark thereon the localities of the respective beds or deposits of the various mineral substances discovered; and, on the completion of the survey, to complete a memoir of the geology and mineralogy of the state, comprising a complete account of the leading subjects and discoveries which have been embraced in the survey.

6. It shall be the duty of the state geologist to forward to the secretary of state, from time to time during the progress of the survey, such specimens in triplicate of the rocks, ores, coals, soils, fossils and other mineral substances discovered and examined, as may be proper and necessary to form a complete cabinet collection

of specimens of the geology and mineralogy of the state; and the said secretary shall cause one set thereof to be deposited, in proper order, in some convenient room in the state capitol, there to be preserved for public inspection, and another set with the state university, and another with the city of St. Louis, to be deposited by said city in some convenient place, or with some public institution in that city, for public inspection.

7. For the purpose of carrying into effect the provisions of this act, the sum of ten thousand dollars is hereby annually appropriated, for the term of two years, to be expended under the direction of the Governor; provided, however, that the salaries of the said state geologist and his assistants shall not commence until they shall have entered upon the execution of their duties; and upon presentation by the said state geologist of the proper vouchers, the auditor of public accounts is hereby required to draw his warrant on the treasurer for the amount of the cost of any chemical apparatus or other outfit deemed necessary by said state geologist, and also for the amount of the quarterly pay of the said state geologist and his assistants, on presentation of the proper vouchers by said state geologist, and upon the order of the governor, who shall be satisfied that the services for which such pay shall be demanded have been performed: provided, that the amount of such cost and pay shall not in any one year exceed the amount herein appropriated.

8. The said state geologist and his principal assistants, before entering upon the discharge of their duties, shall each take an oath before some judge or justice of the peace faithfully to perform all the services required of them under this act, and to abstain from all pecuniary speculations for themselves or others in the objects of their survey during its progress.

9. The annual salary of said state geologist shall not exceed three thousand dollars; the annual salary of the principal assistants shall not exceed fifteen hundred dollars, and the pay of subordinate assistants or servants shall not exceed one dollar per day for every day of actual service.

10. Before appointing said state geologist, as provided for in the first section of this act, the governor is requested to correspond with men of science on the subject, with the view of procuring the services of a person entirely suitable and competent.

11. This act is to take effect from its passage.

Approved February 24, 1853.

THE ORGANIZATION OF THE FIRST GEOLOGICAL SURVEY.

Pursuant to the instructions of this law, Prof. G. C. Swallow was appointed State geologist, by the Governor in 1853. Prof. Swallow came directly from Maine, where he had been engaged in teaching. This survey continued in active operation until June, 1861, under the direction of Prof. Swallow. With him were associated, at different times, and for various periods, Prof. A. Litton, as chemist, Dr. B. F. Shumard, as paleontologist and assistant geologist, Mr. F. B. Meek, Mr. G. C. Broadhead, Mr. Henry Engleman, Dr. J. G. Norwood, Dr. John Lock and Mr. C. Gilbert Wheeler, as assistant geologists, and

Mr. R. B. Price, Mr. Fred Bass, Maj. F. Hawn, Mr. Warwick Hough, Mr. Edward Harrison, Mr. P. C. Swallow, Mr. Daniel Crosby and Mr. H. A. Uppers, as assistants.[1]

The controlling plan of this work seems to have been that expressed by Prof. Swallow in the letter of transmittal accompanying his second annual report, where he states:

> "*It has been our aim to make out:*
> *First, an outline of the Geology of the State.*
> *Second, a general view of the mineral wealth of the mining districts.*
> *Third, an exposition of the Agricultural and Manufacturing resources of the State.*
> *Fourth, report in detail upon as many counties as possible.*"

THE REPORTS OF THE FIRST GEOLOGICAL SURVEY.

Five reports were published by this Survey, but the second is the only one which embodies the results of the work, and this is the one generally known as the Swallow Report. The others are reports of administration and descriptions of progress.

The First Annual Report is under date of November 10, 1853, and consists of a report of progress of four pages. It was printed and published under the same cover with the Second Annual Report. Prof. Swallow there recounts, in a general way, what the operations of the Survey had been during the preceding season.

The Second Annual Report was transmitted under date of December 1, 1854. It is a volume divided into two parts of 207, and 240 pages respectively, containing 69 illustrations and 5 county maps; it was published at Jefferson City in 1855. The contents are as follows:

PART I.

Chapter I. *Geology of Missouri*, pp. 77. This is a generalized description of the geology of the State; the rocks are classified and assigned provisionally to various formations, and their characteristics are given.

Chapter II. *Economical geology, Soils*, pp. 34. This treats, in a similar generalized manner, of the mineral products of economic value; including reference to the soils, to coal, iron, lead, zinc, copper, silver, gold, nickel, cobalt and manganese, and to building materials, cement, paints and clays. There are also short notices of the then partially developed lead mines of Southwest Missouri.[2]

Chapter III. *Special Report on Marion County.* 15 pp. This is a brief systematic statement descriptive of the distribution and characteristics of the geological formations occurring in the county, accompanied by a description of the economically important minerals thus far discovered. A small map giving the outline of the formations and the location of important mines, on a scale of three miles to the inch, accompanies this, and the report is further illustrated by views and sections.

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[1] The First and Second Annual reports of the Geological Surveys of Missouri, by G. C Swallow, 1855.

[1] Missouri Geological Surveys. Historical Memoir, by G. C. Broadhead. Transactions of the Academy of Science, St. Louis, Vol. 4, pages 611 to 614.

2 Broadhead Hist. Memoir, page 619.

Chapter IV. *Special Report on Cooper County,* 17 pp. This is similar in character to the report on Marion county, but no map accompanies the Cooper county report.

Chapter V. *Geology of the Southwest,* 5 pp. This is principally descriptive of certain sections constructed through Southwest Missouri.

PART II.

Dr. Litton's Report on Lead Mines and Mining of Southeast Missouri, in the counties of Franklin, Jefferson, Washington, St. Francois and Madison. This report describes the mode of occurrence of the [lead] ores, analyses, product and sketches of some mines. It also includes a preliminary report on copper mines of Franklin county, and of the most important iron mines of Southeast Missouri, with 48 analyses of ores, rocks, etc.[1]

F. B. Meek, Special Report on Moniteau County, pp. 22. County report with map.

F. Hawn, description of the formations along the Han. & St. Joseph railroad, with a catalogue of fossils collected.

Dr. Shumard's Report. Geological Section on the Mississippi River, 17 pp.

Special Report on Franklin County, with map, 12 pp.

Special Report on St. Louis County, with map, 16 pp.

Palæontology, pp. 24, including a description of 48 new species of fossils, with three plates of same.

Appendix, 31 pp., containing a list of publications previously made relating to the Geology of Missouri. A paper on the use of fossils, a catalogue of the fossils of Missouri and of her trees and shrubs, and a glossary of Geological and other scientific terms.

This completes the first report in which any attempt was made to describe systematically and comprehensively, the geology of the State as a unit. It is largely, and necessarily, of a generalized nature; it deals with the general classification of the rocks and other broad questions which had first to be settled before questions of detail could be entered into. Considering the limited time in which it was prepared and the short acquaintance of the director with the special subject, it stands, truly, a monument to Professor Swallow's ability, to his energy in gathering so much material and to his discernment in classifying it.

In marked contrast to this are, however, the succeeding reports of this Survey.

The Third Report of Progress was transmitted in December, 1856, and is of 4 pages. It recites briefly what work has been done during the years 1855 and 1856.

The Fourth Report of Progress was made in December, 1858, and is of 14 pages. This describes, in greater detail, the operations of the survey during the years 1857 and 1858, and gives, in tabular form, a statement of progress to date.

The Fifth Report of Progress of December 30, 1860, is of 13 pages and is a similar statement of operations during the years 1859 and 1860, with a brief reference to the results reached concerning the coal, lead and iron deposits and the soils of the State In this report the product of the Survey to that time is given in tabular form. According to this there were:

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[1] See Broadhead Hist. Memoir, p. 619.

1.	Counties in which field-work was finished	80
2.	Counties in which field-work was half done	13
3.	Counties in which field-work was commenced	13
4.	Counties in which little or no work was done	7
5.	Counties of which maps were engraved or printed	19
6.	Counties of which maps were drawn and not engraved	25
7.	Counties of which maps were commenced	62
8.	Counties of which maps were not commenced	7
9.	Counties of which reports had been made	33

THE WORK OF THE FIRST GEOLOGICAL SURVEY.

The Survey continued in active operation until June, 1861; but, during the time which intervened between this and the date of the Fifth Report of Progress, it is not probable that much, if anything, was accomplished. Disregarding, however, what may have been produced during this year, we are led to inquire what became of the results of the six years of work intervening between the date of preparation of the Second Report and the year 1861. The labors of the Survey during this time had evidently been centered upon the systematic county work leading to the production of special county reports and maps, such as are presented by the reports on Marion, Cooper and other counties in the Second Annual Report. The table contained in the Fifth Report of Progress shows that much had been done in this direction. In the Second Annual are contained five of the county reports, with accompanying maps, referred to in the table above. During the life of the First Survey Prof. Swallow also made an official report on the Southwest Branch of the Pacific Railway, of 93 pages; and he, and his assistants, published a number of papers relating to the geology of Missouri in Periodicals, and in the proceedings of Societies. Further, during the progress of the Second Survey, in 1873, a volune of 323 pages was issued, containing reports on twenty counties, of which nine were accompanied by maps, all of which were inherited from the First Survey in a condition ready for publication. It is probable that others of such reports were used in the preparation of the county descriptions contained in the Pumpelly Report of 1873 and the Broadhead Report of 1874, hereinafter to be mentioned. Similarly we have, on file in the office of the present Survey, a mass of notes and rough reports in a more or less fragmentary condition, relating to twenty-one counties, which were among the old Survey material. Much of this is, however, in too rough a condition to be put to direct use, and only the person who collected the notes could so systematize them as to make them available; individuals, some of whom are now dead, and others of whom are scattered to various parts of the country. But, even were it practicable to put these reports into condition for publication, the information which they contain is now so antiquated as to make them hardly worth the cost of publication. Thus, regarded even in the most favorable light, we must consider the last six years of the Swallow Survey as poor results when compared with the first two years; and we must deplore as lost a great part of the fruits of these six years of labor. It is difficult to assign this loss to any single cause; several reasons are apparent, and of these the most important are probably the catastrophe of the war, mistakes in the administration of the Survey, and the absence of a definite policy governing such work on the part of the State.

THE PERIOD BETWEEN THE FIRST AND SECOND SURVEYS.

Not long, however, were the interests of the mineral deposits of the State allowed to be neglected. Even before the close of the War we have a petition by James McKenzie to the Legislature,[1] the object of which is to secure the publication of information concerning the resources of the State for foreign distribution.

In the report of the Corresponding Secretary of the Board of Agriculture for 1865,[2] the importance of a scientific survey is dwelt on, though no definite conception seems to have existed as to how such a survey could best be made. In the report of the secretary for 1866[3] the need of geological work finds again expression; and at the meeting of the Board of Agriculture in December, 1867, a resolution is passed to memorialize the General Assembly to appoint a State geologist.[4]

The first movement on the part of the Legislature in response to these solicitations was the passage of a bill in 1866 authorizing Professor Swallow and Mr. L. D. Morse to publish the manuscripts of the Geological Survey. The idea was, however, abandoned on account of the expense.[5] In 1867 a memorial was presented to the Legislature from the St. Louis Academy of Science, earnestly advocating the re-establishment of the Geological Survey, and calling attention to the loss which will result if no provisions were made for the publication of the results of the work done during the years immediately preceding the war.[1] In the message of Governor Fletcher, January, 1869, we find the recommendation that the means should be provided for the preparation of a report on the geology of the State.[2] It appears that, in 1865, a State Board of Immigration had been created, and it is for the purpose of supplying information for distribution by this Board that the preparation of this report is recommended. In the message of Governor J. W. McClurg,[3] immediately succeeding this, in January, 1868, much space is devoted to a consideration of the resources of the State, and the need of making the existence of these resources widely known is especially emphasized. He pays tribute to the value of the Swallow report, and recommends the further publication of detailed information.

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[1] See Senate Journal, Appendix, Adjourned Session, 22d General Assembly, 1863. pp. 31-32.

[2] See Appendix Senate Journal, Adjourned Session, 23d General Assembly, 1865-6, pp. 151-276.

[3] See Second Report, 1866, pp. 160-164.

[4] See Third Report, 1867, pp. 17-18.

[5] Historical Memoir of Missouri Geological Surveys, page 614.

The effects of this message were immediate, or, otherwise expressed, the continued neglect of the interests involved had at last aroused public attention, and, on March 24, 1870, an act was passed creating the Second Geological Survey of the State. The provisions of this act are in the main the same as those of the act creating the First Survey; it differs, however, in some particulars, of which, perhaps, the most prominent is that the Bureau is placed under the control of a Board of Managers of nine members, whereas by the provisions of the first act the State geologist is subject to the directions of the Governor alone.

THE SECOND GEOLOGICAL SURVEY OF MISSOURI.

The act creating the Second Geological Survey of the State reads as follows:

AN ACT TO ESTABLISH A MINING, METALLURGICAL AND GEOLOGICAL BUREAU FOR THE STATE OF MISSOURI, AND TO PROVIDE FOR ITS SUPPORT AND MANAGEMENT, AND TO AUTHORIZE A GEOLOGICAL SURVEY.

Be it enacted by the General Assembly of the State of Missouri, as follows:

SECTION 1. There is hereby created and established a bureau of mines, metallurgy and geology for the state of Missouri, and the same shall be in the charge and under the control of a board of managers, consisting of the governor (who shall be the president of the board) and one member from ecah congressional district, who shall be appointed by the governor and hold their offices for the term of four years, and until their successors are appointed and confirmed.

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[1] See Appendix House Journal, 24th General Assembly, page 125. Jefferson City, 1867.

[2] See House Journal, Regular Session, 28th General Assembly, page 26, Jefferson City, 1869.

[3] See Senate Journal, Adjourned Session, 25th General Assembly, pages 13, 14 and 16. Jefferson City, 1870.

SEC. 2. The governor shall, as soon as the board of managers is constituted as provided in the preceding section of this act, by and with the advice and consent of said board, appoint a fit and competent person as state geologist, and said state geologist may appoint, subject to the approval of the board of managers, one assistant state geologist, who shall be a skillful analytical and practical chemist, to assist him in the discharge of his duties; and the said state geologist may employ such other subordinate assistants as may be found necessary.

SEC 3. It shall be the duty of said state geologist and his assistant, as soon as may be practicable after their appointment, to commence and carry on, with as much expedition as may be consistent with minuteness and accuracy, a thorough mineralogical and geological survey of the state, and determine the extent, value, order, succession, arrangement, relative position, dip or inclination and comparative magnitude of the mineral deposits, and the several strata or geological formations within the state, and also determine the extent of the agricultural, horticultural and vine lands, and their adaptability to the varied products of the soil, and also to determine the extent and capacity of the water powers of the various streams, and shall also make full and complete assays and analyses, as they may deem necessary, of all minerals, soils and other substances necessary for a full, complete and satisfactory report of the materials discovered and so treated.

SEC. 4. It shall be the duty of the said state geologist to make a monthly summary of his work, and forward the same to the president of the board of managers for publication, and shall also, on or before the first day of December in each and every year during the time necessarily occupied by said survey, make a full report of the progress of said survey during the preceding year, which shall be accompanied by such maps, drawings and specimens as may be necessary and proper to exemplify and elucidate the same, and deliver the same to the aforesaid president.

SEC. 5. It shall be the duty of the said state geologist, upon completion of the survey, to represent, or cause to be represented, upon proper maps of the state, by distinctive lines, marks and appropriate colors, the area and magnitude of the various beds of different minerals, valuable rocks, marl, agricultural, vine and horticultural lands, and the various interesting or anomalous stratified rocks discovered, and the water powers aforesaid, and shall accompany the same with a complete memoir of all the minerals, rocks, agricultural, vine and farming lands thus delineated, as well as the water-courses required by this act to [be] examined, and shall embrace within such memoir a full, entire and accurate account of the leading discoveries made in the state, and also a glossary of the scientific terms used in the report; and the said report, so made, when (being) completed, shall be deposited with the board of managers.

SEC. 6. It shall be the duty of the state geologist to forward to the president of the board of managers, from time to time during the progress of the survey, such specimens, in triplicate, of the rocks, ores, coals, soils, fossils and other mineral substances examined, properly labeled, giving the names of such specimens and the localities from which they were taken, for the purpose of forming a complete cabinet of specimens of the mineralogy and geology of the state. One set of said specimens shall be placed in the School of Mines and Metallurgy, whenever the same shall be established; one set shall be placed in the State University, and the other shall be preserved in such manner as the board of managers may direct; and the said specimens shall be open to public inspection at all reasonable hours, under such regulations as are necessary for their proper care and preservation.

SEC. 7. The state geologist and his assistant, before entering upon the discharge of their duties, shall each take an oath, before some officer of this state qualified to administer oaths, that they will honestly, faithfully and fairly perform all the duties required of them by this act. to the best of their abilities, and that they will not permit any person to have access to any of their books or papers, or communicate their contents to any person or persons, and that they will not disclose or make public any mine or valuable deposit otherwise than in their official report to the board of managers, and that they will abstain from all speculations in their own behalf, or in behalf of others, during the progress of such survey, and in relation thereto.

SEC. 8. The annual salary of the state geologist shall not exceed three thousand dollars; the annual salary of the assistant shall not exceed two thousand dollars, and the pay of the subordinate assistants shall not exceed, for each of them, the sum of one dollar and fifty cents per day for each day employed.

SEC. 9. The board of mangers of the bureau herein provided for shall have a superintending control over the survey and reports contemplated by this act; shall have power to make yearly agreements with the State geologist and his assistants as to the amount of their salaries; to appoint a committee of their body to examine, audit and allow all necessary expenses of their survey as they occur, and to certify the same to the governor; to remove from office, for cause, the said State geologist or any of his assistants; and so soon as possible after their organization under this act, should they deem the best interests of the State require it, they shall provide for the establishment, at the most accessible point in the State of an office assayer of ores. And when so established, the governor of this State, by and with the consent of said board, shall appoint an assayer for such office, whose duties shall be prescribed by the board of managers, who shall by contract determine the amount of, salary which in no case shall exceed the sum of two thousand dollars per year.

SEC. 10. The said board of managers shall demand and take possession of all the geological reports of this State, published and unpublished, instruments, implements, and all other paraphernalia which were used in connection with the geological surveys of this State, by the former geologist employed by the State. And all persons now in possession of the same, are hereby authorized and required to turn the same over to the president of the board of managers of the bureau herein established, and when received, the said board shall have power to turn the same over to the State geologist, or make such other disposition of them as they may deem the best interest of the State demands.

SEC. 11 The president of the said board of managers of said bureau, shall receive all the reports of the state geologist by this act, shall lay the same before the board of managers for their consideration and approval, at their annual meeting, to be held at any time, at the discretion of the president, before the meeting of the General Assembly, and after the day fixed by this act when the state geologist is required to make his annual report, and at such meeting the president shall lay before said board an accurate account of all expenditures incurred in prosecuting the objects for which this bureau has been created, all of which after the action of the board thereon, shall be laid before the General Assembly, at the first following session, by the president.

SEC. 12. The board of managers herein provided for, shall be allowed as a full compensation their necessary expenses whilst attending to any of the duties required of them by this act, the accounts therefor to be made out under oath and filed with the State Auditor, and the pay of the state geologist and his assistants shall be out of the appropriations applicable to the payment of other civil officers of the State.

SEC. 13. The sum of seven thousand five hundred dollars is hereby appropriated out of any money in the State treasury not otherwise appropriated, to defray the general expenses of the bureau created by this act, and no larger amount shall be expended for such purpose in any one year. The president of the board of managers is hereby authorized to certify to the State Auditor, from time to time, the sums of money required to pay the salaries of the state geologist and his assistants and for the general expenses of the bureau, and on receiving such certificates, the Auditor shall draw his warrant on the Treasurer of the State for the requisite amounts in favor of the parties and persons entitled to receive the same, and shall charge the several sums so paid to the account of the proper appropriation.

SEC. 14. This act shall take effect and be in force from and after its passage.

Approved March 24, 1870.

THE SURVEY UNDER A. D. HAGER.

Under this law, Albert D. Hager, of Vermont, was appointed State geologist by the board, and the headquarters of the Survey were established in St. Louis. Mr. Hager had been connected with the Vermont Survey and was associated with Professor Hitchcock.[1] Mr. Hager held the position until August, 1871. He published one report[2] of progress of 21 pages, in which he briefly notices the chief building stones and minerals of the State. This report and the work of the Survey is referred to in Governor McClurg's message of January, 1871.[3]

The law was amended March 18, 1871 and the board made to consist of four members besides the Governor, and the limit of the annual expenses was fixed at $10,000 in place of $7,500 previously allowed.[4]

After Mr. Hager's resignation, Dr. J. G. Norwood was in temporary charge of the Survey until November, 1871. Under Dr. Norwood, Mr. G. C. Broadhead was appointed assistant, and Mr. C. M. Litton subassistant.

THE SURVEY UNDER RAPHAEL PUMPELLY.

On November 25, 1871, Mr. Raphael Pumpelly was appointed State geologist. He had studied at Freiburg, had been a professor in Harvard college and was at one time employed by the Governments of China and Japan in geological investigations.[5] He resigned from the position in May, 1872.

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[1] Broadhead Historical Memoir, page 615.

[2] See Appendix Regular Session Twenty-sixth General Assembly, 1871; pp. 21-43.

[3] See Senate Journal, Regular Session, Twenty-sixth General Assembly; page 22, Jefferson City, 1871.

[4] A copy of this law is contained in the Preface to the Report of the Geological Survey of Missouri on Iron Ores and Coal Fields of 1872. Raphael Pumpelly, Director.

[5] Broadhead Historical Memoir, page 617.

Up to the time of Pumpelly's appointment very little had been made public of the results reached by the Survey, and the changes in management must necessarily have much retarded the work. But in his message of December, 1871, Governor B. Gratz Brown commends the Survey warmly to the Legislature; he dwells upon the importance of the interests which it represents, and points out the need of such work for their development, and further recommends an increase in the appropriation.[1]

Pursuant to this recommendation, the law was amended in March, 1872, and the sum of $20,000 was appropriated annually for the salaries and expenses of the Survey.[2] During Mr. Pumpelly's management of the Survey the Board of Managers consisted of Governor B. Gratz Brown, *ex officio* president, Mr. Edwin Harrison, Professor Sylvester Waterhouse, Mr. Forrest Shepherd and Gen. J. H. Hammond. Governor Brown was succeeded in 1873 by Governor Silas Woodson. Professor Waterhouse and General Hammond resigned in the summer of 1872, and their places were filled by Mr. A. W. Meyers and Mr. L. A. Brown. Mr. A. A. Blair was appointed Secretary of the Board.

The assistants of the Survey under Pumpelly were Mr. G. C. Broadhead, Dr. Adolph Schmidt, Mr. Regis Chauvenet, Chemist, Mr. W. E. Guy, Prof. W. B. Potter, Mr. C. J. Norwood, Mr. J. R. Gage and Mr. Alexander Leonhard. Other sub-assistants employed at different times were Mr. John Pumpelly, Mr. P. N. Moore, Mr. F. Tunica, Mr. C. Gayler, Mr. B. Vitzthun von Eckstadt, Mr. W. Bartlett, Mr. T. J. Caldwell, Mr. T. A. Minor, Mr. A. J. Puls, Mr. A. Hoeber and Mr. M. F. Healy.

The plan of work adopted by Pumpelly recognized two classes of investigation. One was the study of the general stratigraphic geology of the State; the other was the study of the distribution and manner of occurrence of the various important mineral deposits, which latter should be put in charge of specialists, or men whose previous experience should prove them to be specially adapted to this difficult work. In harmony with this plan, the work on the general stratigraphy was divided into five departments: *i. e.*, a survey of the Northwest, a survey of the Southwest, a survey of the Northeast, a survey of the Southeast, a survey of the Porphyry region of the Southeast. The work relating to economic geology was divided into three departments, namely, a Department of the Iron Ores and Metallurgy, a Department of Ores other than Iron, a Department of Fuels and Construction Materials other than iron and wood.

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[1] See House Journal, Adjourned Session, 26th General Assembly, pp. 26-7. Jefferson City, 1871.

[2] See Preface of Report of 1872 on Iron Ores and Coal Fields, p. 11.

During the year 1872 the study of the general stratigraphy of the Northwest and the Northeast was begun and work was done in the Porphyry region of the Southeast in the vicinity of Pilot Knob. In the departments of economic geology the distribution and mode of occurrence of the iron ores was studied and many analyses of these ores and of coals were made. The future work at that time outlined for this department included an extension of the study of the iron ore deposits, a study of the lead, zinc, nickel and other ores, and a study of the building materials of the State, for which a laboratory for experimental tests was needed.

Under the Pumpelly management two reports were issued in 1873. The first was an octavo of 323 pages and consisted entirely of county reports. It represented all of the previously unpublished results of work done before the war which was transmitted in a condition ready for publication.[1]

It contains chapters on Maries, Osage, Warren, Shelby, Macon and Randolph counties, by G. C. Broadhead; on Miller, Morgan and Saline counties, by F. B. Meek; on Ozark, Douglas, Wright, Laclede, Pulaski, Phelps, Crawford, Cape Girardeau, Perry, Ste. Genevieve, Jefferson and Clark counties, by B. F. Shumard. The reports are of about the same length and are similar in character to those published in Swallow's report of 1855; they are illustrated by views, sections and maps. The second report, transmitted in April, 1873, is a large octavo of 655 pages.[2]

It is divided into two parts as follows:

PART I.

Chapter I. Notes on the geology of Pilot Knob and its vicinity, by Mr. Pumpelly.

Chapter II. Analyses of ores, fuels and pig irons.

Chapters III, IV, V and VI, constitute a partial report on the iron ores of Missouri, by Dr. Schmidt. They include a general description of the distribution and character of the ores, special descriptions of the different classes of the ores and a list of the iron ore deposits of the State. This subject is handled systematically, scientifically and ably; but the report bears evidence of having been hurriedly prepared.

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[1] Reports on the Geological Survey of the State of Missouri, 1855-1871, by G. C. Broadhead, F. B. Meek and B. F. Shumard, Jefferson City, 1873, pp. 324 and IV.

[2] Geological Survey of Missouri, Raphael Pumpelly, Director. Preliminary report on the Iron ores and Coal fields from the field-work of 1872. With 190 illustrations in the Text and an Atlas. New York, Julius Bien, 1873, p. XVI, 214 and 441.

PART II.

Chapters I, II, III, IV, V and VI contain general matter relating to the coal fields, by G. C. Broadhead.

Chapters VII and VIII are on the geology of Lincoln county, by Wm. B. Potter.

Chapters IX to XV are reports by G. C. Broadhead on Livingston, Clay, Platte, Buchanan, Holt, Atchison and Nodaway counties. They are of similar character to the county reports contained in the earlier volumes of the survey.

Appendices A, B and C contain respectively the results of some tests of strength of building materials, a note relating to Missouri rocks which admit of a fine polish, and a list of Coal-Measure fossils.

THE SURVEY UNDER GARLAND C. BROADHEAD.

After Mr. Pumpelly's resignation, Mr. G. C. Broadhead was elected State Geologist, and assumed charge July, 1873. Under him there remained Dr. A. Schmidt, as assistant geologist, Mr. Regis Chauvenet and Mr. Charles S. Norwood as chemist, and Mr. Alexander Leonhard, Mr. P. N. Moore, Mr. H. H. West, T. J. Caldwell and C. Heinrich as assistants.

The policy governing the Pumpelly Survey seems to have been continued in the Broadhead work, though more was done in the preparation of county reports than was done previously. During 1873, in the Department of Economic Geology, the examination of the iron ores was continued, and, in addition, the examination of the lead deposits of the Southwest was begun. Surveys for county reports were further made in Jasper, Cedar, Barton, Vernon, Bates, Howard, Linn, Adair and Sullivan counties. In 1874 the lead deposits of Cole, Miller and other central counties were studied, and examinations for county reports were made in Putnam, Schuyler, Chariton, Cole and Madison counties.

One report was issued by the Broadhead Survey.[1] This is a large octavo of over 700 pages, transmitted in August, 1874, and contains the following matter:

Chapters I and II contain an historical introduction and a brief description of the general geology of the State.

Chapters III, IV and V treat in a general way of caves and water supply, and of soils and timber, and the last chapter contains a brief list of the minerals of the State.

Chapter VI contains remarks on the Southwest coal field, and is accompanied by a general section.

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[1] Report of the Geological Survey of the State of Missouri, including Field Work of 1873-74. With 91 illustrations and an atlas. Garland C. Broadhead, State Geologist. Jefferson City, 1874; pp. 784, L. 4, 56.

Chapters VII to XXI, inclusive, are reports on Cedar, Jasper, Barton, Vernon, Bates, Howard, Sullivan, Adair, Linn, Putnam, Schuyler, Andrew, Daviess, Cole and Madison counties.

Chapters XXII to XXVIII constitute a report on the lead region of Southwest Missouri, in which the general characteristics of the region and its ores are given, together with a description of a number of its deposits.

Chapters XXIX to XXXII treat similarly of the lead deposits of Central Missouri.

Chapter XXXIII contains rules for the development of iron ore deposits.

Chapter XXXIV is on the lead region of Southeast Missouri.

Chapter XXXV is on the iron ore of the same region.

Appendices A, B, C and D are brief papers on the History of Lead Mining in Missouri, on "Lead Mines in Upper Louisiana," on "Metallic Statistics," and on "Mineral Springs of Missouri." Appendix E contains results of analyses of ores, fuels and minerals.

The Survey was discontinued after the year 1874, and most of its working material was transferred to the State School of Mines at Rolla, of which the president, Dr. Chas. P. Williams, was made acting State geologist, with a nominal appropriation. Little field work seems to have been carried on under Dr. Williams, and, after the year 1876, no further support appears to have been extended to the work by the State. One report was prepared under Dr. Williams, which consists of a small octavo of about 200 pages.[1] It contains a chapter on the "Mineralogy and general Metallurgy of Lead," one on the "Zinc Industry of Missouri," one on the "Iron Industry," and one on "Shannon county." In the appendices are given statistics of lead and zinc and a "Note on the Occurrence of Gold in Northwest Missouri."

A SUMMARY OF THE RESULTS OF THE EARLIER SURVEYS.

THE PUBLICATIONS.

Summarizing the results of this early work, we find that we have inherited the following as published matter:

1. 1885. Swallow's report of 240 pp. with plates and small maps.
2. 1855–1861. Swallow's Third, Fourth and Fifth Reports of Progress, together 26 pages; no illustrations.
3. 1859. Swallow's Report on the Southwestern Branch of the Pacific Railroad of 93 pages, with plates and one map.
4. 1871. Hagar's Annual Report of 23 pp., no illustrations.
5. 1855–1871. Broadhead's, Meek's and Shumard's county reports published in 1873 of 324 pp., with plates and small maps.
6. 1872. Pumpelly's report of 655 pp., with illustration and a large atlas.
7. 1873. Broadhead's renort of 734 pp., with illustrations and a small atlas.
8. 1876. William's report of 177 pp., with a few illustrations.

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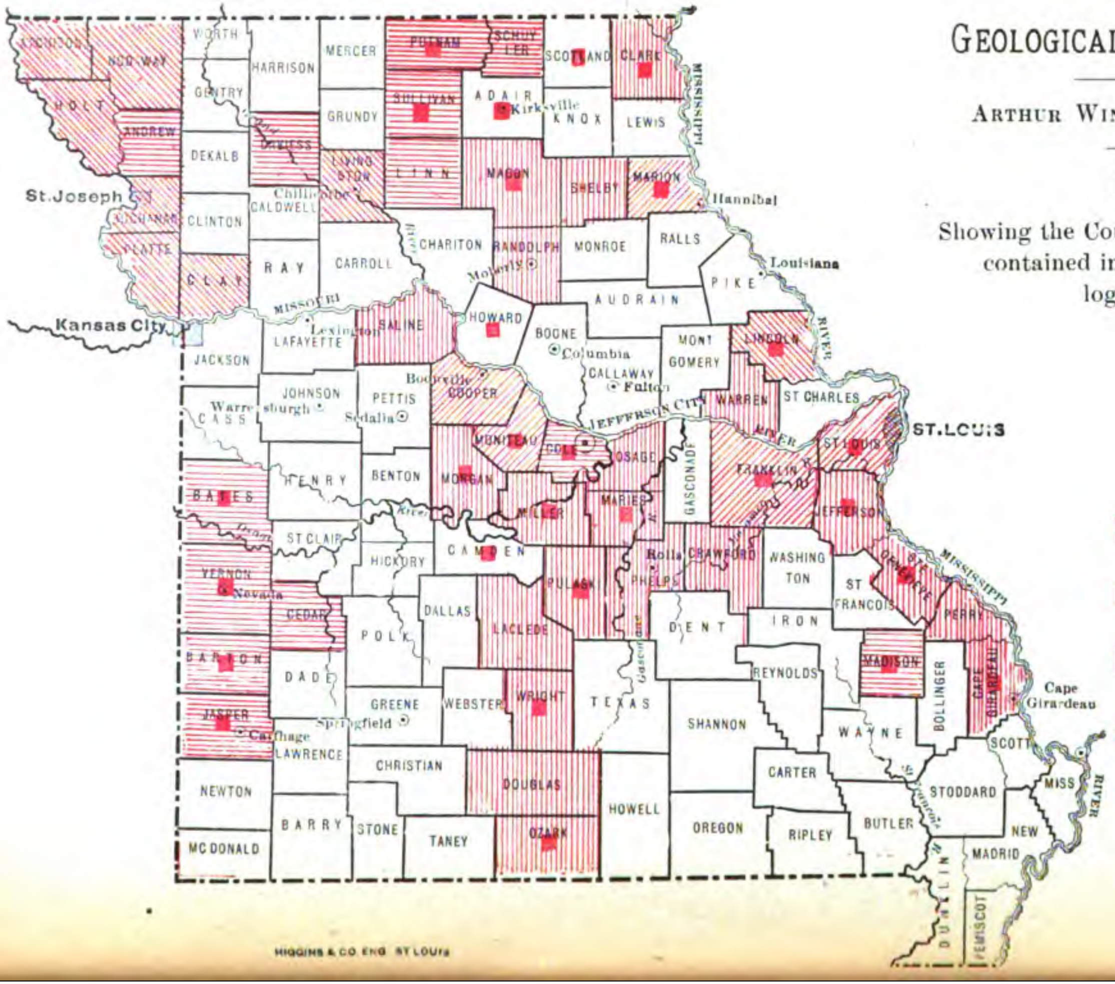
[1] Geological Survey of Missouri Industrial Report on Lead, Zinc and Iron, together with Notes on Shannon County and its Copper Deposits. By Chas. P. Williams, Ph. D., Acting State Geologist. Jefferson City, 1877; pp. 177 and XVI.

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

DIAGRAM

Showing the Counties of which Special Reports are contained in the Publications of earlier Geological Surveys of the State.



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LEGEND.

- ▨ In Swallow's Report of 1855, 5 counties.
- ▥ In Broadhead's et al. Reports of 1871, 21 counties.
- ▨ In Pumpelly's Report of 1871, 10 counties.
- ▤ In Broadhead's Report of 1873, 15 counties.
- ■ Indicates that maps are printed of the respective counties. 28 counties.

Examining these publications critically, we find that the contained reports may be separated into two classes: First, there are reports relating to special subjects which are the products of what we may call subject work. No such reports are, strictly speaking, contained in the Swallow publications, excepting the report of 23 pages, with plates, on paleontology at the end of the Second Report. Such might properly have been prepared in connection with the examination of the mining districts or the exposition of the "Agricultural and Manufacturing Resources," which he states to be among the objects of his work.[1] In the Pumpelly and Broadhead surveys such reports were produced from what was classed as the Department of Economical Geology, and the special subjects of work were the iron ores and the lead and zinc ores of the State.

The second class of reports are what we may call Area Reports or reports devoted to a general description of special areas In the Swallow, Pumpelly and Broadhead publications, the county reports especially belong to this class. The plan of the county reports was originally framed by Professor Swallow, and five of such reports are contained in his Second Annual Report. They vary in length from 12 to 22 pages, and consist of matter of a general nature relating to the hydrography, forestry, agriculture, general or stratigraphic geology and economic geology. They are sometimes, but not always, accompanied by a small page map of the county described, on a scale of three or four miles to the inch. These maps show, generally, the distribution of the geological formations, and the location of mines and furnaces. The amended law of 1871 required the preparation of county reports, and Swallow's plan for these area reports seems to have been followed in the Pumpelly and Broadhead Survey, and, in the three volumes published between 1873 and 1875, forty-three such county reports are contained. In all, there have been forty-eight such county reports published, distributed as follows:

In Swallow report of 1855	5	county	reports.
In Broadhead, Shumard and Meek report 1855–1871	20	"	"
In Pumpelly report 1872	8	"	"
In Broadhead report 1873	15	"	"

On the map of the opposite page is shown what counties were described in these reports, and which in each; further, the counties of which maps accompany the descriptions are indicated.

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[1] See page 15 of this report.

THE COLLECTIONS OF THE EARLY SURVEYS.

The act creating the Survey in 1853 provided for the collection, in triplicate, of such specimens of rocks, ores, coals, soils, fossils and other mineral substances discovered and examined, as may be proper and necessary to form a complete cabinet collection of specimens of the geology and mineralogy of the State. One set of such collections was to be arranged in a room in the State Capitol for public inspection, another set was to be for the State University, and the third set was to be for the City of St. Louis, to be arranged in some place convenient for public inspection. According to Broadhead,[1] this distribution was never made, on account of the interruption of work by the war, and the whole collection remained packed in boxes at Columbia. The law of 1870 provided similarly for the collection of specimens in triplicate, one set being intended for the School of Mines, another for the State University, the third was left at the disposal of the Board of Managers, and apparently assigned by them to Washington University, in St. Louis. These collections were partly distributed in 1875 according to the law, while those not divided remain in the museum of Washington University arranged in cases. In 1884 the specimens of the Swallow Survey at Columbia were unpacked and partly arranged in the University museum; the greater portion, however, is in trays in a basement room of that institution. From this portion a few hundred specimens were furnished the present Survey for reference.

THE APPROPRIATIONS.

The appropriations for the Geological Surveys preceding the present were, according to Broadhead,[2] as follows:

From 1853 to 1862	$105,000 00	
1870 and 1871	12,500 00	
Under Acts of 1872, 1873 and 1874	60,000 00	
In 1876 and 1877, and by School of Mines	5,000 00	
Printing, 1873	12,000 00	
Printing, 1876	1,500 00	
Total	$196,000 00	
Unexpended appropriations	19,814 45	
Total expended		$176.185 55

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[1] Hist. Memoir, page 622.

[2] Hist. Memoir, page 618.

Of this total, there was expended for printing:		
Swallow's Report, 1854	$5,000 00	
Report 1855-1871	3,000 00	
Pumpelly, etc., 1873	9,000 00	
Broadhead, etc., 1874	7,320 00	
Williams' report, 1876	1,500 00	
Total for printing	$25,820 00	
Leaving a total for salaries and field and other expenses		$150,365 55

THE PRESENT SURVEY.

From the cessation of the work, in 1876, to the inauguration of the present Survey, nothing further was done by the State in the direction of a Geological Survey. It was directly upon the foundations laid by these early Surveys that the present Survey had to build; the results which had been reached nearly twenty years ago furnished the latest available information. To expand from this beginning without duplicating labors became our duty; yet, at the same time, this could not be done arbitrarily; due allowance had to be made for the enlarged requirements which new discoveries, new developments, and the growth of the country had created. This called for careful consideration and nice discrimination.

THE LAW GOVERNING THE PRESENT SURVEY.

The act creating the present Geological Survey was approved May 13, 1889. The law at present governing the Survey is framed upon the same general plan as that of the last Survey, but differs in details. Among the most noticeable differences are the absence of a requirement to collect specimens in triplicate, the diminution of the amount allowed for salaries of assistants, and the absence of the clause requiring county maps and reports to be prepared.

This law is as follows:

AN ACT TO PROVIDE FOR A BUREAU OF GEOLOGY AND MINES TO COMPLETE A GEOLOGICAL AND MINERALOGICAL SURVEY OF THE STATE OF MISSOURI.

Be it enacted by the General Assembly of the State of Missouri, as follows:

SECTION 1. There is hereby created and established a bureau of geology and mines for the state of Missouri, which shall be under the direction and in charge of a board of managers, which shall consist of the governor, who shall be *ex officio* president of the board, and four citizens from the state at large, who shall be appointed by the governor, by and with the consent of the senate, and shall hold their term of office four years.

SEC. 2. The board of managers are authorized, as soon as they are organized, to appoint one state geologist, who shall be a person of competent, scientific and practical knowledge of the sciences of geology and mineralogy, and who is not connected with any school or college as instructor, who shall be the director of the survey; and said geologist may appoint such assistants and subordinates, assistants and laborers as may be deemed necessary in order to make a thorough scientific, geological and mineralogical survey of the state.

SEC. 3. It shall be the duty of the state geologist and his assistants, under the instruction and direction of the board of managers, to carry on, with as much expedition and dispatch as may be consistent with minuteness and accuracy, a thorough geological and mineralogical survey of the state already begun, with a view to determine the order, succession, arrangement, relative position, dip or inclination and comparative magnitude of the several strata or geological formations within the state, and to discover and examine all beds or deposits of mineral contents and fossils, and to determine the various position, formation and arrangement of the many different ores, clays, rocks, coals, mineral oils, natural gas, mineral and artesian waters and other mineral substances as may be useful or valuable; also to note carefully the character of the soils and their capacities for agricultural purposes, the growth of timber and other scientific matters that may be of practical importance and interest; and said geologist shall cause to be represented on the map of the state, by colors and other appropriate means, the various areas occupied by the different geological formations in the state, and to mark thereon the localities of the respective beds or deposits of the various mineral substances, and, on the completion of the survey, to complete a memoir of the geology and mineralogy of the state, comprising a complete account of the leading subjects and discoveries which have been embraced in the survey.

SEC. 4. It shall be the duty of the State geologist to make or cause to be made, detailed maps and reports of counties or districts as fast as completed, which maps shall embrace all such geological, mineralogical and scientific details necessary to make complete reports of said districts or counties. The State geologist may also, from time to time, publish or cause to be published any reports of work completed, in the form of pamphlet or bulletins for general distribution.

SEC. 5. It shall be the duty of the State geologist to collect full suits of all minerals, rocks, ores, fossils or other mineral substances of scientific or practical interest or utility as may be discovered, and that may be necessary to form a complete cabinet collection, to illustrate the various resources of the State, as may be necessary to assist in preparing the various reports of the survey.

SEC. 6. It shall be the duty of said assistants to make full and complete examinations, assays and analyses of all such rocks, ores, soils or other substances as may be submitted to them by the State geologist for the purpose, and to furnish him with a detailed and complete account of the results so obtained.

SEC. 7. The State geologist, from time to time, may furnish items of general information or new discoveries for publication in newspapers: Provided, the preparation of the manuscript and publication thereof does not interfere with the progress or add to the expense of the survey; he may also have authority to furnish cabinets for colleges or public museums, located within the State of Missouri, of minerals, rocks or fossils: Provided, said institutions shall pay the expense of preparing, labeling, transporting and putting up said collection; and also, further, that in the selection of said specimens the general State collection is not deprived of duplicates of the same, and that the State collection is not seriously injured.

SEC. 8. The board, with the State geologist, may determine the place for the State cabinet and headquarters of the survey.

SEC. 9. It shall be the duty of the board of managers to report to each General Assembly the progress and condition of the survey, an accurate account of money spent, and such reports of the State geologist and his assistants as have been completed, together with all such information as may be deemed necessary and useful.

SEC. 10. The board shall have power to take possession of all property of former surveys, whether reports, maps, collections, instruments or other property belonging to the State, and all persons now in possession of the same shall deliver them up to the order of the president of the board of managers: Provided, that no cabinet or library already arranged shall be removed, but the State geologist and his assistants shall have the power at any time to examine or study such collections in preparing their reports.

SEC. 11. The board may make such by-laws and regulations for the government and control of its meetings and labors of the State geologist and his assistants as may be deemed necessary.

SEC. 12. As full compensation for the members of the board of managers they shall be allowed their necessary expenses while attending to the duties assigned them by this act. The board shall fix the salary of the State geologist, not to exceed three thousand dollars per annum, and his chief assistant, which shall not exceed one thousand eight hundred dollars per annum, for the principal assistant or palæontologist, if one is employed, not over one thousand eight hundred dollars.

SEC. 13. The state geologist may, with approval of the board, appoint other necessary assistants, whose pay shall not exceed five dollars per day, and such other necessary laborers or assistants as may be necessary, who shall receive a fair compensation for their work. He shall also have power to negotiate for such chemical work, chemical apparatus and chemicals as may be necessary, and may, from time to time, with the approval of the board, have such work done. He may also, with the approval of the board, employ special assistants in palæontology, provided it be deemed necessary.

SEC. 14. All accounts of salaries and expenses shall be made under oath, and certified by the board, and filed with the auditor of the state.

SEC. 15. The board of managers shall have the general management of the survey, and have full power to remove the state geologist and appoint his successor, when deemed necessary for the good of the work entrusted to him; and the State geologist shall have full control over his assistants, and have power to remove them when necessary.

SEC. 16. For the purpose of carrying out the provisions of this act, the sum of twenty thousand dollars is hereby appropriated, or so much as may be needed thereof.

SEC. 17. The board of managers, the state geologist and each of his principal assistants shall, before entering upon the discharge of their duties, take the usual oath of office to faithfully perform all the services required of them under this act, and to abstain from all pecuniary speculations for themselves or others in the objects of their survey during its progress.

SEC. 18. The president of the board shall, from to time to time, certify to the state auditor the sum of money required to pay the salaries of the state geologist and his assistants and the incidental expenses of the bureau; and on receiving such certificates, the auditor of the state shall draw his warrant on the treasurer of the state for the requisite amount in favor of the parties and persons entitled to receive the same, and shall charge the several sums so paid to the account of the proper appropriation.

SEC. 19. All previous acts and parts of acts inconsistent with this act are hereby repealed.

SEC. 20. The importance of the completion of the geological and mineralogical survey of Missouri at an early day, creates an emergency within the intent and meaning of the constitution, which requires this act to take effect at once; therefore, this act shall take effect and be put in force from and after its passage.

Approved May 13, 1889.

THE ORGANIZATION OF THE PRESENT SURVEY.

I was elected State geologist by the present board of managers on August 29, 1889. I assumed the duties of the office September 20, 1889.

The governing ideas in the organization of the present Survey was that the work should be in the line of development of that of previous Surveys, and should be adjusted to the requirements of to-day, so far as was consistent with the instructions of the law. In section 2 of this law provision is made for *"a thorough scientific, geological and mineralogical survey of the State."* In section 3 it is required that this shall be carried on *"with as much expedition and dispatch as may be consistent with minuteness and accuracy;"* and section 4 provides for the preparation of detailed maps and reports, and pending the completion of such the State geologist, is authoized to publish any reports of work completed, in the form of pamphlets or bulletins for general distribution. Section 5 requires the formation of a State cabinet.

In accordance with these ideas, the two classes of work which were recognized as existing during the progress of the earlier surveys, namely: Subject-work and Area-work were recognized here.

SUBJECT-WORK.

Subject-work, we have seen, was first properly begun under the Pumpelly administration, evidently in recognition of the fact that more detailed and authoritative information was required than had heretofore been furnished through the reports of the earlier Surveys. A report containing the results of such subject-work is designed to include general facts of distribution for the whole State concerning a special substance; it is designed to meet the demands from those who wish to know whether a certain substance exists in the State, where it exists, and how, and what its qualities are. Details as to distribution cannot, of course, be given in a report of such comprehensive nature, it must necessarily be somewhat generalized in this respect; it can only indicate the locality where this special substance exists, without attempting to define the limits of the occurrence. In the discussion of the properties of substance, it can, however, be exhaustive; the breadth of the field of work allows opportunity for the study of a great variety of material, permitting interesting comparative study. Similarly, in the discussion of the origin of the material, of the nature and future of the industries which mry be dependent upon it, such a report can be complete. In short, all which has broad and general bearing can and should receive full treatment here. Details which have local value only cannot be attempted here.

Subject-work is almost a necessity to-day. At the date of the early surveys it was possible for one man to be an authority on a number of subjects pertaining to geology, and, thus, reports could be prepared by one man relating to everything which he might encounter during the progress of his work. In this period of specialists, such is no longer possible. A man to be an authority on any one subject must give his chief attention to that special subject, and must continue to do so for a considerable time. The subjects of work of the Survey are assigned to separate individuals. These individuals are, or become, thus, specialists in their subjects of work, and their final products will be authoritative. This specialization of the work seems to be in accordance with the provision of the law, that *"a thorough scientific"* survey of the State should be made.

AREA WORK.

Area work, however, in distinction to subject work, is designed pre-eminently for the purpose of giving detailed local information. It is calculated to meet the demands for information concerning certain areas. A man, who may or may not be a property-owner, may desire information concerning a special area in which he is interested; he does not want to know so much whether certain things exist in the State, but he wishes to know whether a certain definite locality has something or anything of value. Thus, area work should deal mostly with that which is given a subordinate place under the subject work; and, *vice versa,* the topics of general applicability, which are exhaustively treated under the subject work, should take a subordinate place in the area work. Results obtained in the progress of this area work are, however, to be utilized in the preparation of area reports; some repetition in publication will, of course, occur, but no duplication of field work need arise. In this work the maps will generally constitute the most important part, though their scale and the detail contained on them will vary according to the importance or the intricacy of the area. A perfect map would be an exact miniature of the surface which it represents, and the nearer it approaches such a miniature the more valuable it becomes. The use of maps is expanding constantly, and the art and skill displayed in their construction and production has grown proportionally. It is designed, in connection with the present work, to construct maps according to modern methods; and, hence, a few remarks will be in place concerning the essentials of such maps, the extent to which they have been adopted, and the information which they furnish.

Maps properly constructed present in a condensed form facts which it would be almost impossible to describe in words; all the details of location and distribution are there seen at a glance. A comprehensive conception of the relation of parts is obtained through the study of a good map, which can be obtained in no other way, and this with none more than with geologic maps. Regarding maps as miniatures of the surface, representation of the topography naturally becomes essential; and, hence, in all advanced systems of mapping, both in this country and in Europe, topographic work has played an important part. It is a trite axiom in geologic work that topography should precede geology. Hence, we find that, with almost all geological surveys in which detailed stratigraphic work has been attempted, topographic maps have been constructed, where such were not already available. "'A perfect geological map," says Geikie, Director-General of the Geological Survey of Great Britain, "should represent: 1st, a full and accurate topography, with the form of the surface and heights in contour lines, shading or otherwise; [1] 2d, all geological deposits, from the most recent to the most ancient, with their boundary lines accurately traced and the relation of their distribution to the external form of the ground clearly depicted." Says Lesley, State Geologist of Pennsylvania: "The topography is always our best guide to the geology. In the coal regions this is especially true. Every lineament of the surface indicates a mood in the geology beneath, so that the whole face of the earth, like the countenance of a man, is instinct with living expressions of its past experience." [2] A topographic map "is fundamentally necessary for a geologic map," says Powell, Director of the United States Geological Survey. "'A proper geologic map cannot be made without the basis of a topographic map." [3] "It is an impossible thing to make a good geologic map of the country without having as a groundwork a good topographical map of the country," says Alexander Agassiz. [4] Whitney, formerly State geologist of California, when writing of the Mississippi Valley States, remarks that the topography is of a kind "which requires a very minutely detailed study of the geology to be laid down with accuracy." [5] Says Prof. Cook, late State geologist of New Jersey: "At the beginning of the survey no such work as is here given entered into our plans. But as the successive reports appeared, and as the attempts at descriptive geology were made, it became apparent that, for the study and preparation of useful geological reports, it was necessary to have accurate maps—maps which would show the location of all the important geographical points, and also the outlines and elevations of the hills and valleys, and their heights above the sea level." [1]

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[1] Outlines of Field Geology, by Archibald Geikie, p 83.

[2] A Manual of Coal and Its Topography, by J. P. Lesley, p 82.

[3] Testimony before a Joint Commission on the Organization of certain Bureaus of the U. S. Government, pp. 8 and 9, 1884

[4] Same, p. 1015.

[5] Geographical and Geological Surveys, by J. D. Whitney, p. 85. From North American Review, July and October, 1885.

In this country topographic surveys have been prosecuted in connection with the geological surveys in the States of Pennsylvania, New Hampshire, New Jersey, Virginia, Michigan, Wisconsin, Texas, Arkansas, California, and also with the National surveys under King, Powell and Wheeler. Other States have prosecuted geological work without the aid of topographic maps, but this has been because the nature of their work has been largely such as did not call for accurate maps (2)

In Europe well nigh all geological surveys have been prosecuted upon the basis of topographic maps already constructed, and, where such maps have not existed, topographic work has been done in conjunction with the geologic work. The excellence of the maps constructed by these foreign Surveys, and the amount of money expended on them has hardly anywhere been approximated in this country, and this evidence of their value we cannot afford to overlook here. However much we may disapprove of the foreign form of government, or of foreign social organization, we are obliged to admit that the European nations both more thoroughly appreciate the value of natural resources, and give more thought to their development.

As has already been intimated, topography and geology are not two distinct subjects, but certain aspects of topography are essentially geological. In the character of the topography is expressed, both the nature of the rocks which make up the mountains, the hills, and the valleys, as well as the nature of the forces which have produced these features of relief. A topographic line is very often a geologic line; the outline of a mountain or hill is very often the outline of a geological formation. Topography, combined with other features of geology on a map, furnishes innumerable facts relating to altitude and thickness of formations and deposits, in addition to those of area and distribution which would be shown on an ordinary diagram. With a topographic map in hand one is able to recognize features on the ground, which, with an ordinary map, are only very vaguely defined. A hill or a mountain is a prominent and recognizable feature in the landscape; if such a hill be represented on the map, the position of any mineral deposit, geologic division line or other fact of interest can be shown definitely and clearly on the summit, at the foot, or on the slope, as the case may be, and its position on the ground can be readily found. Without such delineation of the topography the location of the occurrence is necessarily vague; one does not know with certainty whether it is on a hill or in a valley.

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1 Geological Survey of New Jersey. Final Report of the State Geologist, Vol. I, 1888, p. 2.

(2) It is by no means maintained that no geological work can be done without the aid of such maps; valuable results can be reached in the study of the paleontology, of the lithology, of the mineralogy of the State, and elaborate researches can be carried on for the purpose of determining the properties of materials, all without maps of any kind. Further, diagrams or generalized maps showing the distribution of the larger formations, and the general location of the occurrences of minerals and other substances, can be made without the assistance of topography. But, if we wish to enter into detail, if we wish to show with any degree of precision the actual mode of occurrence of individual ore-beds, veins or other deposits of limited dimensions, topographic maps will become indispensible, and the more detailed the investigations which are made in any region, the more practically valuable they are. In fact, says Whitney, "it is only work which is detailed and thoroughly accurate that can be trusted and used where problems of importance, involving a considerable expenditure of money, are to be solved." (Opus cite, p. 85.)

In the case of all bedded deposits, whether they be coal beds, or beds carrying lead or zinc, topography furnishes valuable information concerning the relative vertical positions of different beds, as well as concerning the depths of such beds beneath the surface. On a map without topography, the outcrop lines of the two beds, one above the other, would appear simply as sinuous lines, and no information would be conveyed concerning the interval between these beds, nor as to their depths beneath the surface at any point. In a country which varies locally in altitude two hundred feet or more, these facts are of great importance and very much affect the value of any property. In the instances cited, they determine whether a coal bed may be reached by a shaft twenty feet deep, or by one two hundred feet deep; they determine the dip of the bed and the positions of the anticlines and synclines, which are facts of importance in mining operations; again, if we take the case of a topographic map of the Archaean and Lower Silurian areas of Southeast Missouri, such a map shows whether the granites, the porphyries, the limestones, are in the hills or in the valleys; it shows the maximum altitude reached by the limestones or their residual products, and thence the altitude of the old sea level; it shows whether the ores or the workable stone is located in positions that are easily accessible and from which the materials can be readily worked; it shows the location of favorable sites for the development of water powers; it indicates the amount of overflow which damming at any locality may produce. The topographic map further furnishes the best possible basis for the construction of an agricultural map, which is made part of the work of this Survey; it permits at once of the division of the lands into flat, plateau, or hill-top lands, into slope lands, into bottom lands, and all other agricultural questions dependent upon topography can be readily determined.

The facts contained on the topographic and geologic map are not of two distinct kinds, and are not collected separately and independently in the case of this Survey; in fact, the data for the topography would be almost entirely collected in prosecuting the detailed work for the stratigraphy, and the facts of the topography are of indispensable assistance in solving the geological problems, the results of which are presented in a final map. The outlines of the hills, their altitudes, the positions of the different beds on their slopes all have to be noted whether the topography is accurately plotted or not, in order that we may obtain sufficient facts for delineating details of stratigraphy and distribution; the plotting of the topography along with such notes is, in short, only a systematic method of recording a multitude of observed facts. These facts, when carefully plotted upon such a map, are presented in the best possible form for study and comparison, and it is only through such presentation that many important results can be deduced; thus, the data for such a map must very often be collected, in a large part, whether such map is ultimately prepared for publication or not.

For these reasons topographic maps were deemed necessary in connection with this area work. In the older reports, as already stated, county reports were similarly the results of area work, but the information which they contain is not sufficient to satisfy the requirements of to-day. At the time when these reports were planned, little was known of this country, and a mere statement of the existence of various subtances was valuable information. Not even the existence of the different geological formations of the State was demonstrated, and the first labors of the Survey were necessarily directed towards classifying these large formations and towards defining their areas. These general facts of existence and distribution are now pretty well established, and what is wanted nowadays, is not alone the information that a certain thing exists in a certain county or district, but exactly where and how it exists in such district is further demanded. In recognition of this, it was thought best, in planning for the area work of the Survey, not to continue with the preparation of county reports similar to those which had been prepared by the earlier Surveys, but to enlarge upon this plan in order to meet the requirements of the day. This seems to be necessary, in order to fulfil the conditions of the law specified in section 4, requiring the preparation of detailed maps and reports. Thus, where, with the old plan, maps of whole counties were made on a scale of three or four miles to the inch, maps for the present work have been constructed on a scale of one mile to the inch, and each sheet represents only a portion of the county. The area of such a map is a quarter of a square degree of latitude and longitude, the size of each sheet being about 13⅝x17⅜ inches, not including the margin. By this means maps are obtained of a uniform size, and the area represented is one permanently defined, it is not subject to change by subdivision or otherwise, as is a county. It is in harmony with a plan of publication which is becoming more and more adopted by Government Surveys.

Similarly, while the older reports deal mostly in generalities concerning the areas described, the new reports will endeavor to be as specific as possible, and will embody a great deal of detail.

THE PLAN OF PUBLICATION.

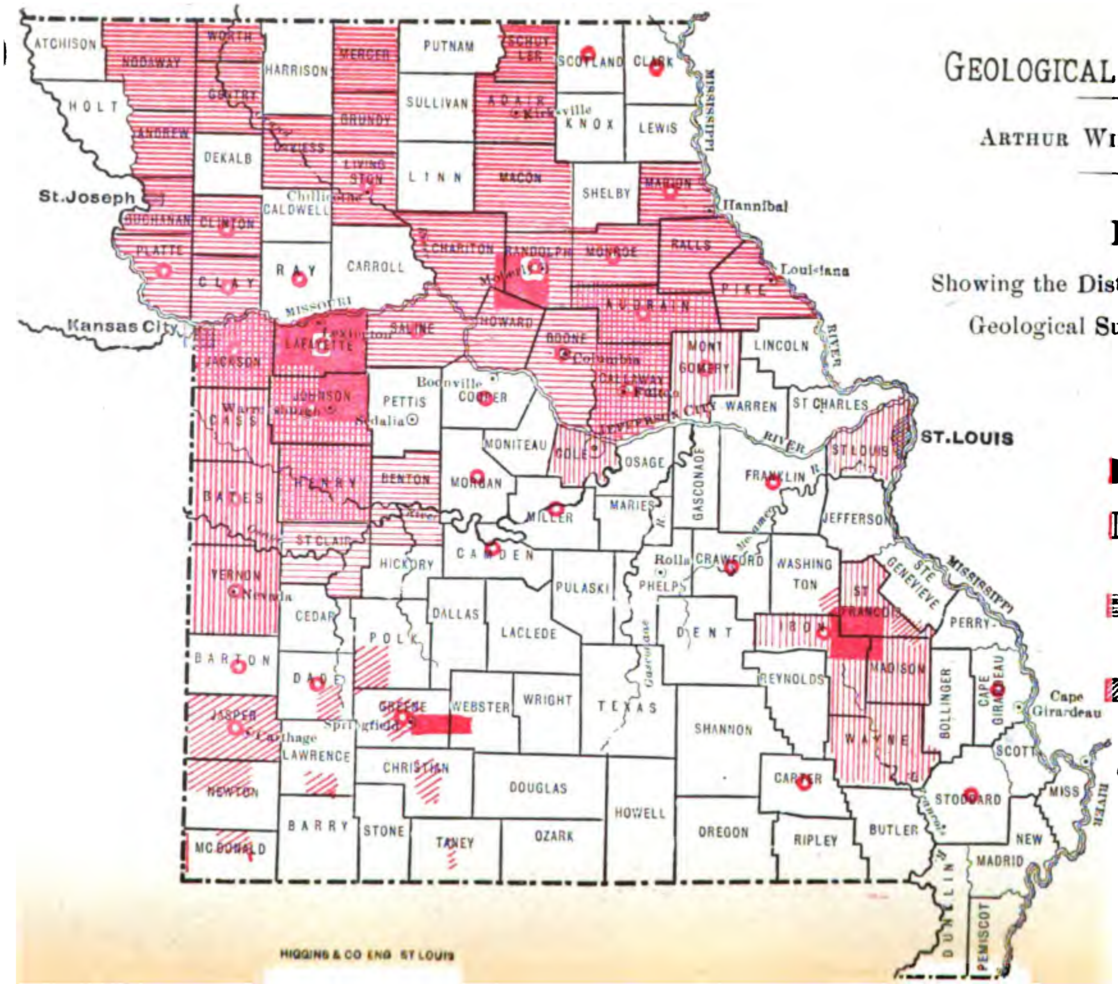
These general plans of work being settled, the next question to be decided was how the results should be prepared and published. To complete the examination of any one important subject in the State calls for one or two years of work, and, similarly, to prepare detailed maps of any considerable area requires a correspondingly long time. The demand is, however, urgent for information concerning many subjects and many localities; further, many facts are collected in the progress of the work which are of temporary value and which ought not to be withheld for the preparation of final reports or monographs. To meet this demand for information, and to supply a means of ready publications, the bulletins of the Survey were designed. The matter which they contain is essentialy provisional and is somewhat hurriedly put together, but they are calculated to become very useful. They partially satisfy the demand for information and avert the danger of publishing what should be a complete report, before sufficient time has been

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

DIAGRAM.

Showing the Distribution of the Work of the Geological Survey, during the year 1890.



LEGEND.

■ Areas which have been mapped in detail.

▥ Counties in which clays and structural materials have been examined. 16 counties.

▤ Counties in which mineral waters have been examined. 31 counties.

▨ Counties in which zinc and lead deposits have been examined. 11 counties.

○ Counties in which the coal deposits have been examined or which have been inspected by the State geologist for other purposes. 35 counties.

allowed for the collection of sufficient data for the preparation of a complete report. These complete or final reports, according to the plan proposed, will be published ultimately in separate volumes, one volume to each subject of importance. The results of the detailed area work will similarly be published in separate form, each sheet or map and accompanying sections being in a separate cover or atlas, and each such atlas being accompanied by a small pamphlet report descriptive of the area.

THE WORK IN PROGRESS.

By referring to the contents of the reports of the earlier Surveys, given in the preceding pages, it will be seen that the subjects of work which have heretofore received most attention are the iron ores of the State and the lead and zinc deposits; the coal deposits have also received some attention, but this has been more in connection with the area or county work than as a part of a general and special work devoted to coal deposits. In organizing the present Survey, the following subjects were selected as worthy of first attention.

1. THE COAL DEPOSITS.
2. THE CLAYS, BUILDING STONES, LIMES, SANDS AND CEMENTS.
3. THE MINERAL WATERS.
4. THE ZINC AND LEAD DEPOSITS.

In Bulletin No. No. 1 there was given a statement of the progress of the work of the Survey up to April, 1890, and it will be unnecessary to repeat here what was there given. On the map opposite this page the distribution of the work, up to the end of 1890, is shown graphically and needs no further explanation. In addition to this, however, we will add a few remarks concerning the character of the work and the progress which has been made since last April.

THE WORK ON THE COAL DEPOSITS.

Work in the coal fields has been prosecuted by the earlier Surveys, but the character of the work done was such as to furnish only general information as to the existence of coal, and very little is given from which one can determine the actual areas underlain by individual beds, or the depth beneath the surface at which these beds occur. Further, so many developments have been made since the operations of the earlier Surveys that much more can be determined concerning these details than would have been at that time possible. These facts led to the selection of the coal deposits as one of the subjects for detail study, and led, further, to the selection of the coal region as the area in which a large portion of the detail mapping could be most effectively prosecuted.

The work in the coal fields may be divided into two parts: First, that which has been done looking towards the immediate preparation of a preliminary report upon the general distribution and character of the coal in the State. For this purpose inspections have been made in twenty-four counties by myself, as is shown on the accompanying map. Secondly, there has been carried on in the coal region detailed mapping in portions of five counties which has for an object the definition of the area of the individual coal beds. This work has been executed, under the immediate direction of myself, by Mr. Leo Gluck and Mr. C. F. Marbut, assistants of the Survey. During the summer months Mr. C. H. Gordon, a volunteer assistant, was at work with Mr. Marbut in Randolph county. The exact area covered by this detailed mapping is shown on the map above referred to.

THE WORK ON THE CLAYS, BUILDING STONES, LIMES, SANDS AND CEMENTS.

No systematic and critical examination of the clays or of the structural materials of the State has ever been made. A study of the latter was included in the plan of work of the Pumpelly Survey, but seems to have never been started. The only information which we have concerning these materials in the State is contained in the old county reports, or is an incidental part of some other report. The information consists almost entirely of loose and general statements based upon cursory hand examinations; no tests of the materials have been made, and no determinations of their extents instituted. The clays of Missouri rank second to none in the country, and they exist in great quantities. The industries which they have already created give employment to thousands of men, and the value of the products is many millions. They constitute a most important subject of work, which has already been too long neglected. The results of what the Survey has done in this connection already give promise that the report on this subject will be one of the most valuable that could have been prepared.

Since April last the work on the clays and structural materials of the State has been actively pushed, though sickness caused interruption during the latter part of the summer. The work has been extended over fourteen counties by Mr. Ladd, and twenty-three samples of clays and seventy-seven samples of limestone have been analyzed by Mr. Woodward, including five hundred and sixty determinations. Further, experimental tests of the clays are in progress under Professor Wheeler. Mr. Ladd was assisted in the field work during the spring and early summer by Messrs. J. D. Robertson and E. H. Lonsdale. During the autumn, however, he has continued the work alone.

THE WORK ON THE MINERAL WATERS.

The mineral waters of the State have, similarly, been heretofore almost entirely neglected. Missouri has a large supply of such waters, and many of the localities where they occur have been improved at considerable cost, and some are equipped with handsome hotels and well kept grounds. Some of these waters have already a wide reputation, while others of similar composition are hardly known. It is the object in this work of the Survey to determine, in an authoritative manner, the composition of these various waters; to publish the results, and to accompany this with such illustrations and descriptions of the surroundings as will lead to the wider use of these resorts, both for purposes of cure as well as for recreation.

The work on the mineral waters of the State has been continued by Mr. A. E. Woodward intermittently since last spring (part of his time being given to the analyses of clays, and to other miscellaneous laboratory work). Since November he has been assisted in the laboratory by Mr. James D. Robertson. Up to the end of the year Mr. Woodward had visited fifty-three mineral water localities in the State, distributed over thirty-one counties, as shown on the map. He has sampled forty-nine waters and analyzed forty-seven, which includes six hundred and sixty-eight determinations of constituents.

THE WORK ON THE ZINC AND LEAD DEPOSITS.

The lead and zinc deposits have already received attention, it is true, by the earlier Surveys, but the work was interrupted before its completion. Further, the development of these deposits has been so active during the past few years that much attention is attracted to them; the demand for information concerning them is very urgent, and there is nothing published on hand for distribution. As a result of this, an investigation of the zinc deposits of this and adjoining States has been ordered by the Secretary of the Interior through the United States Geological Survey. In order to make the results of this

National work in Missouri directly and immediately available to the State, and, further, in order to prevent duplication of labors, co-operation between the National and the State Survey was arranged for, so far as this special subject was concerned. Mr. Walter P. Jenney was assigned to this work by the National survey, and the co-operative work was begun in the autumn of 1889, as explained in Bulletin No. 1. Early in the progress of operations the value of these deposits became apparent, and attention was called to the fact by the Survey. At the same time the need of detailed work, in order to properly display this fact, was evident; and, pending the completion of this detailed work, a preliminary report from Mr. Jenney was arranged for. Soon after the issue of the Bulletin, in April last, field work on the zinc and lead deposits of the State was suspended by Mr. Jenney, who was in charge of the work, and he returned to Washington for the purpose of preparing the preliminary report, in recognition of an earnest desire of mine. The expectation was then that he would take up field work again during the following summer. Pending his return to the State, Mr. Robertson, who was assigned to him as assistant from the State Survey, was put to other work. Up to the present writing no further field work has been done on this subject. The preparation of his report has occupied all of Mr. Jenney's time. He will resume field work this winter, however, and the expectation is that his investigations will be completed in a few months.

THE WORK ON GENERAL STRATIGRAPHY AND PALEONTOLOGY.

Since the last report of progress the work on general stratigraphy has been prosecuted chiefly with the assistance of the United States Geological Survey. For this purpose, Prof. Henry S. Williams, of Cornell University, assistant paleontologist of the National Survey, has commenced the study of the fossil faunas of the Missouri rocks, as part of a general study in this and adjoining States, which has for its object the definition of the faunal characteristics of the different rocks and their more exact correlation. For this work Mr. Gilbert Van Ingen was assigned to the State last spring, to collect fossils, under the direction of this Survey, to be sent to Prof. Williams for study. Mr. Van Ingen continued uninterruptedly at work until September last, when he was taken down with typhoid fever, and he has not fully recovered yet.

THE AREA WORK.

A great portion of this work, as already stated, has been done in the coal regions; but, in addition to this, an area represented by one sheet has been covered in the iron and granite regions of the southeast by Messrs. E. H. Lonsdale and C. F. Marbut. Mr. Erasmus Haworth, a volunteer assistant, was also occupied in this area during the past summer, studying and mapping the distribution of the granites, syenites and porphyries. His labors were in continuation of work done by him during past years for the United States Survey, and the State Survey was fortunate in thus securing the benefits of his knowledge. Further, work of this detailed character was done in Greene county, under Prof. E. M. Shepard, a local assistant. Mr. Robertson, of the regular force, was assigned to this work for over a month, and Maj. E. W. Newton, of Bolivar, gave additional assistance. Less than one hundred square miles were covered here, however, by the mapping; but the results of geological examinations over the whole area of one sheet have been written out by Prof. Shepard, and are on file at this office. The following table gives the exact area mapped in each district:

In Lafayette County	540 square miles
In Randolph, Chariton and Howard Counties	324 square miles
In Iron, Madison and St. Francois Counties	350 square miles
In Johnson County	250 square miles
In Greene County	110 square miles
Total	1,574 square miles

THE WORK ON THE CABINET AND COLLECTIONS.

A great deal of time, especially during the past few months, has been given to the collections of the Survey. These collections may be divided into two kinds. One, and by far the bulkier portion, is gathered for purposes of study and for analyses and tests. The other portion is for exhibition. For every specimen which comes to the Survey office, a label is written, giving the name of the specimen, its geological position, its composition, and describing exactly where it was found, and referring to the proper note-book for further information. Each specimen is given a separate number, and this number, with a copy of the label, is recorded in the office catalogue. The specimens are all filed away in numbered trays so that any one can be found at short notice at any time. Those exhibited in the cabinet have their number written on them, and special cabinet labels are written, giving the name and the composition of the material and the use to which it is put. These specimens are then mounted and arranged under appropriate group labels. This system and routine is necessary with a large collection in order to preserve an accurate record of where each specimen came from, and of how it was obtained. There are now in the collection of the Survey two thousand three hundred specimens, and of these over seven hundred are arranged for exhibition. Over 130 photographs have been taken by members of the Survey during the past year. These include views of mineral water resorts, of quarries, of mines, of clay works, of rock exposures and other objects relating to subjects of work. Some of these are mounted for exhibition and others will be added later. Since September last, Mr. Robertson has given a considerable part of his time to the arranging and labeling of specimens and other material for the cabinet.

THE WORK IN THE OFFICE.

The work in the office may similarly be divided into two parts: First, that necessary for the preparation of the results of field work for publication. Secondly, that necessary for attending properly to such matters as correspondence, accounts, and the multifarious clerical duties which are a part of every public office. In the first class of office work, all members of the Survey have been more or less engaged, and it has consisted of the plotting of maps, the writing of reports and the correcting of proof. The second class of work has been done chiefly by Mr. J. C. Halligan; all of his time has been devoted to it. Few will realize the amount of the correspondence which is necessary in connection with such a work. Since the beginning of the Survey, not much over a year ago, fully eighteen hundred letters have been written and a corresponding number have been received and read. Many of these contain inquiries concerning minerals of the State, or are solicitations of advice from citizens, and require careful consideration and explicit answers, which call for time in their preparation. Further, every month, the accounts of the Survey have to be made out by all members, have to be carefully scrutinized by me, and have to be submitted to the Governor and Auditor. Further, a report of operations has to be written each month, and some fifty copies of it have to be prepared and distributed. All manuscript that is prepared for publication for the Survey is to be read critically by myself, and is often revised by myself or others. Next, all proof of such publications has to be read and corrected by me, and all other details in connection with engraving, printing and publishing have similarly to receive my attention. Thus, in these administrative matters of the Survey, much time is necessarily spent.

MISCELLANEOUS WORK.

In addition to what has been described, miscellaneous work of various kinds has been done. In the laboratory, analyses have been made of five iron ores, four coals and one sand, including thirty-two determinations over and above the twelve hundred and sixty determinations already spoken of. Further, ninety substances have been determined in the laboratory, about eighty of which were sent in by outside parties who are citizens of the State.

In connection with the detailed mapping, the Survey has received assistance from the United States Coast and Geodetic Survey, in the southeastern portion of the State, where two determinations of latitude and longitude were made, one at Ironton, the other at Potosi. Meridian points were at the same time established at both of these places, which will be of value to the County surveyors in determining the variations of their needles.

THE PUBLICATIONS.

Owing to the short time the Survey has been in existence, we could not expect to have ready for publication, by this time, any final report or monograph. We have practically had only one season of field work, and most of the time, so far, has been spent in the field. Much material has, however, been collected which will make part of such monograph, and, in addition, we have published or have prepared for publication the following preliminary reports:

Bulletin No. 1—85 pp.
Bulletin No. 2—158 pp.
Bulletin No. 3—100 pp.
The Biennial Report of the State Geologist.

During the present winter it is anticipated that there will be prepared for publication the following:

Bulletin No. 4.
Bulletin No. 5.
Bulletin No. 6.
Report on the Higginsville Sheet, Lafayette county.

In addition to this, the areas tabulated on page 43, which have been surveyed in detail, will be plotted this winter. A description of these areas can be written out soon after they are plotted, and can be published, together with the maps, if advisable, during the present year.

THE EXPENDITURES OF THE SURVEY.

The rules regulating the expenditures of the Survey are given in sections 12, 13, 14, 16 and 18 of the law. These fix the limits of the salary of the State geologist and his assistants, and provide under what conditions the funds appropriated for the Survey shall be disbursed. Subordinate to these requirements of the law, the following instructions are issued by the State geologist, in General Circular No. 1:

Expense accounts are to be made out at the end of each month and sent to the Jefferson City office to the State geologist. They should reach the office not later than the second business day of the month succeeding the one which the account covers. These accounts must be itemized and the items arranged according to date, and must be countersigned by the geologist in charge and handed in with his general account to the State geologist.

The accounts should be made out in the ordinary form of a bill against the State geologist, *i. e.*

JEFFERSON CITY, January 1, 1891.

ARTHUR WINSLOW, *State Geologist*,

To [full name]........................., assistant.........................Dr.

date..............................item..................................amount.

Received payment,

[Signature.]

Materials purchased for the use of the Survey must not be entered under the head of Sundries, but the item must be specified.

Railway fare items must state the points from and to which the journey was made. No personal expenses, such as fees, wash bills, medicine, repairs, or purchase of wearing apparel, will be allowed.

It is expected that the members of the Survey will use the strictest economy in regard to the expenses which have to be paid by the Survey. For sums over two dollars, vouchers should be taken, numbered, and handed in with the accounts. In the case of railway fares, however, vouchers are not required.

No allowance will be made for living expenses of salaried assistants while the assistants are at permanent headquarters, or at any branch office or temporary headquarters. While away from permanent or temporary headquarters, expense accounts will be allowed as follows, unless otherwise arranged for:

With occasional and temporary absence any reduction, which can be secured, of expenses at headquarters during the time of such absence must be placed, in the expense account, to the credit of the Survey. Thus, if one's expenses during a week's absence from headquarters amount to $9.00, and the reduction of expenses at headquarters during the same time amounts to $5.00, then the net expense account will be $4.00.

With frequent and prolonged absence, and when no expenses at headquarters have to be carried, only such portion of expenses incurred will be allowed as is over and above what would be a reasonable cost of subsistence at headquarters.

The rate of such cost of subsistence is, until further notice, fixed at $20.00 per month. Thus, if one's expenses during a month's absence amount to $35.00, the net expense account will be $15.00

The expense accounts are to be made out in full in all cases, and the account credited the Survey is to be subtracted from the total, thus:

Total expense account..	$35 00
Allowance on expenses to credit of Survey........................	20 00
Net amount due..	$15 00

All accounts, after being scrutinized, criticised and corrected, if necessary, by the State geologist, are then entered upon one general voucher in the following form:

..............................18....

STATE OF MISSOURI, To.................................. ....Dr.

On account of Bureau of Geology and Mines.

18.... Month	Day.	Salaries and incidental expenses.	Voucher.	No.	
....	......	....	....	...	....
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....	......	....	....	...	....

I solemnly swear the above account is correct and the amount claimed is justly due me.

....

Sworn to and subscribed before me this................day of........... 18....

....

....

The above account is approved by the Board of Managers of the Bureau of Geology and Mines, and I hereby certify that the amount (..................Dollars ....cents) is required to pay expenses of carrying out the provisions of the act of the General Assembly, approved May 13, 1889, and the State Auditor is requested to draw his warrant in favor of ....for said sum of money.

....

President of the Board of Managers of Bureau of Geology and Mines.

...................................18....

The two columns in this voucher are, one for the total amount of the expenditure, the other for the number of the sub-voucher containing the items which go to make up this total. These sub-vouchers are retained in the Survey office for purposes of future reference. After the general voucher for the expenses of the month is made out, it is submitted to the Governor, who examines both the items of the sub-voucher, as well as those of the general voucher, and stamps each one of the former with his office 'stamp, in evidence that it has been inspected by him on the date stamped. The general voucher, if approved by the Governor, is then signed by him, sworn to by the State geologist, and a warrant is given for the amount called for, to the latter, by the Auditor. The State geologist thus becomes disbursing agent for the Survey of the amount thus transferred to him. The following table gives, in classified form, the expenditures of the Survey, from its beginning to the end of the year 1890:

Salaries	$10,494 58
Railway fares	763 28
Subsistence	1,123 71
Postage and telegrams	197 11
Freight and expressage	269 76
Printing	675 20
Office and cabinet furniture	361 20
Office and cabinet supplies	334 42
Field supplies	632 39
Laboratory supplies	624 79
Horse and wagon hire, car fares, etc., etc	609 44
Library	17 00
Engravings and photographs	45 24
Total	$16,148 10

THE WORK OF THE FUTURE.

The calls upon the Survey from many portions of the State would seem to indicate a general interest in, and an appreciation of its work. In order that these demands may be met in a satisfactory way, a larger appropriation must be made for the continuance of the work. The last appropriation of $20,000 has been made to apply for eighteen months; the next appropriation will have to last twenty-four months. If the Survey be continued with the same force, and in the same manner, for the next two years, an appropriation of $26,200 will be necessary.

It is, however, important that the operations of the Survey should be extended. The investigation of the iron ore deposits, especially of the central portions of the State, was never completed by the earlier surveys, and should be resumed and made a special subject of study by a competent man. The zinc and lead deposits of the State call for immediate attention, and this should be provided for in a more liberal manner than heretofore. The work on this subject which is in progress by the National Survey, should, of course, be considered in planning any work on the same subject by the State; but the experience has been that this National work is not sufficiently responsive to the needs of the State, and that if the State wishes to obtain immediately those results specially desired by the State, the work must be under State control. Further, agriculture and forestry are made by law subjects of work of the Survey, and provisions should be made for a thorough investigation of the character and capacities of the soils and for a determination of their distribution. It is desirable that a report should be prepared on the paleontology of the State, and that additional paleontological work be done for the purpose of settling certaintquestions of general stratigraphy, and for the preparation of a geological map of the State. Finally, an addition should be made to the force for the purpose of extending the detailed mapping more rapidly over those portions of the State which are considered worthy of such work. The amount estimated to be necessary for such extensions of the work for two years is $22,200. The total necessary to maintain the present force of the Survey and to provide for the recommended extensions would, therefore, be, in round numbers, about $50,000.

In addition to the special reasons given for an enlargement of appropriations, there is the general one that the work can be accomplished more economically, and the results can be made available sooner through the expenditure of a large sum during a few years than by the expenditure successively of small sums during many years. But further, the proximity of the Columbian Expositon at Chicago creates an additional justification of this demand. This exhibition promises to be the largest ever held in this country, and its importance should certainly be in proportion to the event which it commemorates. Located at Chicago, in the midst of the Central States, the exhibits made by these States must be second to none. Everything will be expected of them, and as they there appear so will they be judged. Thus liberal provisions should be made, not only for a display of the mineral resources of this section, but of all its capabilities and products. But such display should consist not merely of an exhibition of mammoth or unique specimens. To attain the best results, to attract the attention and to command the consideration of the intelligence and culture of the world which will be there assembled, the display must have a deeper significance, must be gathered and arranged with art. In connection with the mineral deposits it is not sufficient that specimens of this and that ore, or clay, or coal be gathered and labeled and piled indiscriminately on shelves; but they should be so arranged as to illustrate how they occur, as to illustrate what products are made from these materials and the processes they pass through. Such an exhibit should be accompanied by diagrams, maps, photographs and publications giving reliable information as to how and where these materials exist. Such a collection once prepared would be, and should be made, of more than temporary value, it would be a valuable foundation for a permanent State exhibit. Hence, for this further reason, it is urgent that means should be provided whereby the Geological Survey can collect and put in shape for publication all of the necessary information.

Few people who have not been engaged in such work, or who have not tried to carry it over a great State like this, so as to produce results which shall be as authoritative as such official work ought to be, realize how small an appropriation of $10,000 per year is, when the magnitude of the interests involved is considered.

Ten thousand dollars represents:

Between ½ and ⅓ of a cent per individual;
One cent per every forty acre tract;
One-fortieth of a cent per acre;
One eight-hundredth of one per cent of the total assessed valuation of property.
One two-hundredth part of the State revenue;
One one hundred and fiftieth part of the total expenses of the State.
One-twentieth of one per cent of the annual value of the mineral products of the State.

The sum represented by an increase in the land value through the work of the Survey, of only five dollars per acre, and of only twenty square miles, would pay for the operations of the Survey, as at present run, for about six years, and this small amount is now in places paid for mining rights in the State upon lands known to be underlain by coal.

An increase of the same amount over two thousand square miles would raise the amount received by the State from taxes by about $20,000 per year.

Ten thousand dollars per year cannot be more than one-twentieth of one per cent of the annual value of the mineral products of the State.

The portions of this ten thousand dollars per year, derived from different sources, is as follows:

From taxes on real property	$5,500 00
From taxes on personal property	1,600 00
From taxes on R. R., Bridge and Telegraph companies	550 00
From license from dramshops, etc	900 00
From taxes on Merchandise and Manufacturing plants	450 00
From Fees and Special taxes, about	1,000 00
Total	$10,000 00

Data are not at hand from which I can state the appropriations made for the geological work in a number of the States which now have Geological Surveys, but a few figures can be given, and they are as follows:

California	$100,000 a year, printing not included
Texas	35,000 a year, printing not included
Arkansas	18,000 a year, printing not included
New Jersey	8,000 a year, printing not included
Georgia (?)	8,000 a year, printing not included

Some idea of the sums necessary for the prosecution of such work may be gathered from the table of the amounts expended for geological surveys by different States. This includes expenses up to the year 1886:

Pennsylvania (second survey), 1874 to 1885	$1,042,040 00
New York, 1838 to 1880	712,000 00
Ohio, 1869 to 1880	355,786 00
Illinois, 1851 to 1875	190,330 00
Missouri, 1853 to 1877	176,185 00
Wisconsin, 1873 to 1879	149,000 00
Michigan, 1871 to 1875	132,000 00
New Hampshire, 1869 to 1878	59,839 00

These amounts include cost of publications as well as of operations in the field. The amounts vary widely, but the results attained are not always proportional to the cost; the reasons for this lie in details of history and of management, which need not be entered into here. All of these sums are, however, very considerable, and they impress one with the fact that, in order to carry on a great work like this, sums which appear large to an individual must necessarily be provided; though, when compared to the wealth of the area and the magnitude of the interests involved, the sums are very small. These facts, it seems to me, ought to be clearly understood before the inception of such work, and then provisions should be made for carrying on the survey according to a definite policy. The people, or the Legislature through its committees, should thoroughly investigate the subject, so as to obtain a clear appreciation of the necessities of the case and of the means required to obtain certain results; they should be perfectly satisfied of the value of those results, and should have a clear conception of the cost of obtaining them, and should then provide, not only for the maintenance of the Survey from year to year, but for its continuation in a proper manner until the work outlined shall have been completed.

Reviewing the history of the Geological Survey of the State given in the preceding pages, we see that its life has been very fitful. It has existed for a few years only to be discontinued before any plan of work was completed and at the sacrifice of much of the result reached. It has been weakened by successive changes of management with accompanying changes of policy. Its trained corps of employes and its equipments for work have been lost during the interim between two periods of activity; its collections designed to illustrate the resources of the State have been scattered, and with it all a considerable sum of money has been expended. Yet the interests which this work is especially devoted to have continued to exist and have continued to demand recognition and will always continue to do so, whether it be through a Bureau of Geology and Mines, through a Board of Internal Improvements, through a Bureau of Statistics, or through a Special Commission. And these facts, true as regards Missouri, are based upon the experience of other States and Nations. Just so surely as it is true that it is conducive to the welfare of the State that the existence, the extent and the nature of its mineral resources should be determined and made known, just so surely will such work be prosecuted. History would teach us that the question is, not whether these facts shall be determined or not, but whether they shall be determined now or later. If determined now, the results will be available at once and the benefits will be felt immediately; if determined later, the beneficial effects will be deferred in proportion. The work is not to be regarded as a luxury which a rich State may afford, but which a poor State may dispense with; it is an investment which will yield good returns to the poor as well as to the rich; it is a work of improvement which will enhance the value of property; a work in harmony with the peace-loving spirit of the age, in accordance with which the energies of the State are being directed more and more toward industrial development.

It would be a difficult thing to express by figures just how much time and money should be charged to the account of organization of the present Survey; but it would represent a very considerable portion of what has been expended. Assistants had to be drilled, methods of work had to be adjusted to local conditions and requirements, general inspections had to be made before work was actually begun, equipment had to be provided. The general plan of work is now well outlined and the members of the Survey are familiar with the details, and all moves smoothly. There is no doubt but that, thus organized, much more could be produced in an equal time in the future than has been possible in the past. The policy of the survey contemplates the completion of certain fundamental work which has not been executed in the past. The largest cost lies in this fundamental work, and, for it, the recommended increase of appropriation is intended. This fundamental work once completed, the work of the future will be only such as is necessary to adjust the results to future developments, in order that they may be kept abreast of the times, and such as is necessary for the proper care of the collections.

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

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BIENNIAL REPORT

1891-92

OF THE

STATE GEOLOGIST

TRANSMITTED BY THE

BUREAU OF GEOLOGY AND MINES

TO THE

37TH GENERAL ASSEMBLY.

JEFFERSON CITY, MO.:
TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS
1893.

GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

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JEFFERSON CITY, MO.:
TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS
1893.

Referred to Committee on Printing, with instructions to confer with the House Committee on Printing and arrange so that same printing will not be done by order of both bodies, January 24, 1893.

The report from the Committee on Printing, recommending that 3,000 copies of said report be printed, was adopted—1000 for the Appendix to the Senate and House Journals, 1000 for the use of the Senate, and the remainder for the office of the State Geologist for distribution, January 25, 1893.

C. Roach, Secretary.

[illegible]
[illegible]
University [illegible]
6-17-1938

PREFATORY LETTER.

JEFFERSON CITY, Jan. 5, 1893.

To the President, Gov. David R. Francis, and the members of the Board of Managers of the Bureau of Geology aud Mines:

GENTLEMEN—I have the honor to submit to you herewith my report of the operations of the Geological Survey of the State during the years 1891 and 1892:

As is tabulated on the first page, twelve subjects of work have engaged the attention of the Survey during the past two years; the first part of the report is devoted to a detailed description of the progress made in each division. The second part of the report consists of recommendations for the future and of an argument for the continued support of the work by the General Assembly.

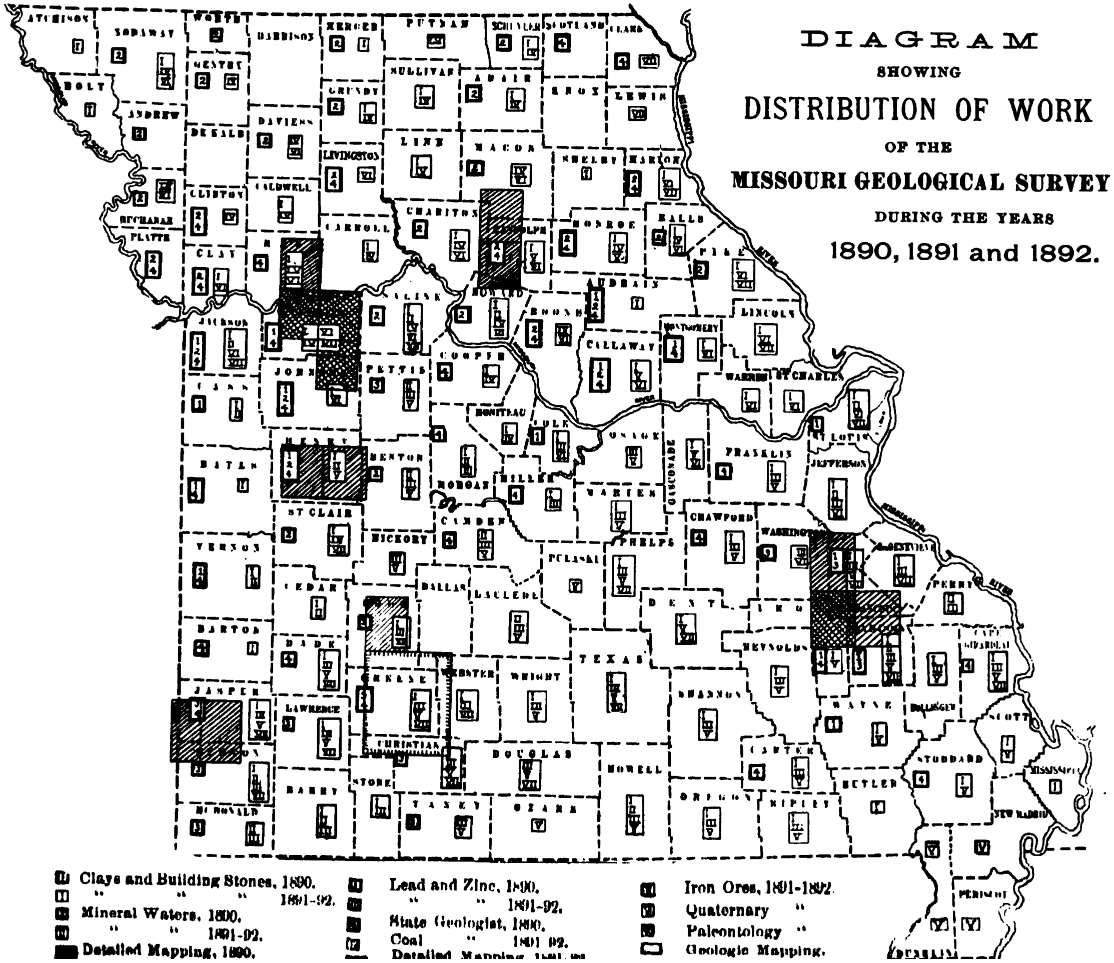
I have again to express my hope that the progress, here outlined, of the work which you have placed in my charge, may be satisfactory to you, and may receive your expressions of approval. I, together with the other members of the Survey corps, have endeavored, to the best of our ability, to so prosecute the work that it will be of lasting credit and benefit to the true welfare of the State.

The past three years of accumulation have brought the Geological Survey to a stage of mature productiveness, and a large amount of material is now gathered in partial preparation for publication; thus much more abundant results may be expected during the immediately succeeding years than the preceding have yielded. I have officially recommended, and my general interest in the work further leads me to hope, that the Survey may receive from the Thirty-seventh General Assembly the same support that was granted it by the Thirty-sixth General Assembly; that a bureau so well started and maintained under your administration may be fostered, at least equally well, by future administrations; that this prosperous and progressive State of the Mississippi valley may take no backward step.

Respectfully submitted.

ARTHUR WINSLOW,
State Geologist.

DIAGRAM
SHOWING
DISTRIBUTION OF WORK
OF THE
MISSOURI GEOLOGICAL SURVEY
DURING THE YEARS
1890, 1891 and 1892.



GEOLOGICAL SURVEY OF MISSOURI.

BIENNIAL REPORT OF PROGRESS

FOR THE YEARS 1891-92.

BY ARTHUR WINSLOW, STATE GEOLOGIST.

The principal subjects of work of the Geological Survey during the years 1891 and 1892 have been:

1. A general examination of the coal deposits of the State.
2. An examination of the iron ores.
3. An examination of the clay deposits, including a chemical and experimental investigation of the qualities of the principal clays.
4. An examination of the building stones.
5. A study of the mineral waters.
6. An examination of the zinc and lead deposits.
7. A review of the metallurgy of lead in the State.
8. A study and review of the paleontology.
9. A study of the crystalline rocks of the Southeast.
10. A general study of the Pleistocene or glacial deposits.
11. Detailed mapping in five sections of the State.
12. General geological mapping in two sections of the State.

Further, among minor subjects of the work, a large amount of statistical material has been collected for the purpose of preparing an historical sketch of the progress of mining in the State, and of the production of minerals from the inception of mining to the present day. For the purpose of preparing a dictionary of altitudes and a hypsometric map of the State, profiles have been collected of nearly all the railroads in the State, and the results of other leveling have been secured. Surveys have also been made for the construction of models to illustrate occurrences of special importance and interest.

In addition to these special subjects of work, large additions have been made to the collections of the Survey, and much time has been given to unpacking and filing, labeling and cataloguing specimens, to arranging the cabinet for their reception and to mounting the specimens in the cabinet. A large number of photographs have also been taken for the purposes of illustration. From the knowledge and material acquired the Survey has been able to render much assistance and to furnish a large number of specimens to the Missouri World's Fair Commission in the interest of the mineral exhibit of the State, which has been placed in charge of the Geological Survey by the Commission. The State Geologist has personally given much thought and time to the preparation and execution of plans for this exhibit.

In the office much time has been spent in the platting of maps and sections, and in preparing reports, in reading proof, in attending to a large correspondence, in preparing and classifying accounts, in distributing reports, and in other minor office duties. Many specimens sent in by the citizens of the State for determination have been examined and reported upon.

In addition to this work prosecuted by the State Survey, assistance has been rendered through the U. S. Coast and Geodetic Survey, and additional geological work has been done on the zinc and lead deposits of the State through the U. S. Geological Survey. Of such assistance and work more will be said later.

1. THE EXAMINATION OF THE COAL DEPOSITS.

The general examination of the coal deposits has so far been conducted by the State Geologist, and has been in continuation of the work prosecuted by him during the year 1890. Since that date investigations have been made by him in the following 25 counties:

Schuyler,
Adair,
Nodaway,
Caldwell,
Linn,
Howard,
Putnam.
Grundy,
Buchanan,
Ray,
Chariton,
Boone,
Sullivan,
Daviess,
Clinton,
Carroll,
Macon,
Monroe,
Ralls,
Saline,
Gentry,
Moniteau,
Lafayette,
Cooper,
St. Clair.

These are designated as having been examined, on the map opposite the preceding page of this report, and it will be there seen that, in all, there have been investigated during the past years the coal deposits of about 50 counties.

The purpose of this work was to obtain general and recent information concerning the coals of the State and the stratigraphy of the Coal Measures, preliminary to more detailed work, and preliminary to an attempt at the correlation of the coal-beds. During this work the coal-beds at all points visited were measured, and, at important localities, average samples were collected for analysis; in addition, along with such inspections, many important drill-hole records were obtained and have been placed on file in the Survey office for future reference and use.

As an outcome of this preliminary work there has been printed, and in large part distributed, a Preliminary Report upon the Coal Deposits of the State. This report contains over 200 octavo pages. As is implied by its title, however, and as is distinctly expressed in the preface, it is essentialy a preliminary report. It is in a large part a presentation of only the bare facts of the occurrence of the coal, the facts of most direct economic importance, and these are presented in a popular way. The justification for the presentation of such a preliminary report lies in the urgent demand for information concerning the subject; but, though this report is calculated to satisfy this demand to a great extent, it should by no means be taken as a measure of all that can be presented, and all that will be attained through the work in the coal regions.

Among the most important works yet to be done in this field is a solution of these problems of stratigraphy, which will result in the correct classification and correlation of the beds or strata of different sections, including the various coal-beds. Further, for the purposes of an exact industrial classification of the coals, it is necessary that chemical analyses be made of all the important beds. During the past two years chemical work has been done on 68 samples of different coals by Mr. J. D. Robertson. In these analyses the ordinary determination of a proximate analysis have been made. In addition to such chemical work, however, in order that the adaptabilities of the coals may be reliably determined, experiments conducted on a working scale are to be recommended. These should include tests for steaming, for coking and for resistance to attrition and exposure of the most representative coals in the State. The results of laboratory and field observation will together indicate what coals are worthy of such experimentation.

For the purpose of defining the limits of the individual coal-beds over different areas, detailed mapping has now been prosecuted in seven different counties in the coal fields, and an area of about 1850 square miles has been covered to date. To complete the definition of these coal-beds, it is necessary that such mapping be continued in this region.

2. THE EXAMINATION OF THE IRON ORES.

The examination of the iron ores of the State has been in charge of Mr. Frank L. Nason, assistant geologist.

Mr. Nason was appointed to his position in June, 1891, and entered upon the discharge of his duties about the middle of the following July. Before coming to the State he was connected with the New Jersey Geological Survey, as assistant geologist under Dr. Cook, in which capacity he gave special study to the iron ores of that State and of the adjoining state of New York. He had, in addition, done a large amount of private expert geological work, especially on the subject of iron ores. He hence came well prepared to take up the work to which he was assigned. During the year 1892 he was assisted in the field and office by Mr. E. H. Lansdale, an assistant of the survey.

Since coming to this Survey, Mr. Nason has made examinations of iron-ore deposits in the State in the following 43 counties:

Howell,
Oregon,
Ripley,
Carter,
Shannon,
Texas,
Reynolds,
Wayne,
Butler,
Stoddard,
Cape Girardeau,
Bollinger,
Washington,
Ozark,
New Madrid,
Wright,
Douglas,
Taney,
Pulaski,
Maries,
Osage,
Christian,
Greene,
Lawrence,
Jasper,
Henry,
Hickory,
Benton,
Laclede,
Dent,
Crawford,
Gasconade,
Franklin,
St. Francois,
Iron,
Randolph,
Callaway,
Madison,
Camden,
Dade,
Pettis,
Phelps,
Monroe,

These are designated on the accompanying map as having been so examined.

This work has included a determination of the general extent of iron ores in the various counties, an inquiry into their origin and an outlining of the general conditions of their distribution. In addition, the qualities of the various ores have been investigated, and a number of samples were collected, of which chemical analyses have been made.

Mr. Lonsdale's work has consisted chiefly in locating and in briefly describing the numerous iron-ore localities shown on the map, in central and southern Missouri, and in this he made excellent progress; over 600 localities have been mapped, of which a large number are described in his report.

The counties in which this systematic work was done are the following:

Bollinger,
Butler,
Carter,
Douglas,
Howell,
Reynolds,
Ripley,
Ozark,
Oregon,
Shannon,
Texas,
Wayne,
Stoddard,
Dent,
Phelps.

As an outcome of this work, the general report on the iron ores of the State, of over 400 pages, is now printed and will soon be ready for distribution. This report is of a comprehensive nature, it outlines the distribution of the different iron ores of the State, it describes the important occurrences, it discusses the distribution and the utilization of the ores, and conveys recommendations concerning the best means for their development. Clearness and graphic interest is added to the report by its numerous illustrations. The map accompanying the volume shows at a glance the distribution of the ores.

The future work on the iron ores of the State should consist largely of systematic and detailed mapping in the iron-ore regions, so that the distribution of the ore bodies may be shown in greater detail, as well as the other surrounding conditions.

The rapid progress which has been made in this work is due to the energy and good judgment which Mr. Nason has displayed. His zeal as a geologist and his experience as a mining engineer have combined to make the task an agreeable as well as an easy one. His unswerving loyalty to his work has brought him the esteem of those with whom he has been associated, his considerate thoughtfulness of others has made him many friends throughout the State.

3. THE EXAMINATION OF THE CLAYS.

The field work for the purpose of determining the distribution and geological position of the clay deposits of the State up to the end of August of the year 1891 was in charge of Mr. G. E. Ladd, assistant geologist. The experimental work of the clays was then, and is still, in charge of Prof. H. A. Wheeler of Washington University, St. Louis. On March 31, 1892, Prof. Wheeler was appointed assistant geologist in charge of both the field and laboratory investigations, and Mr. Leo Gluck of the Survey corps was detailed to assist him.

Mr. Ladd's field work ceased with the end of July, 1891, and his connection with the Survey was severed soon after. Up to the beginning of August of that year he had made inspections of clay deposits in 27 counties. Since March, 1892, Prof. Wheeler has made detailed studies in 42 counties; while Mr. Gluck has made studies in 27 more, besides working in 22 of the counties visited by Prof. Wheeler. The counties thus visited by Ladd, Wheeler and Gluck are as follows, 80 in all:

Jackson,
Pike,
Warren,
Morgan,
Phelps,
Jefferson,
Dade,
Johnson,
Saline,
Texas,
Shannon,
Reynolds,
Adair,
Lincoln,
Carroll,
Vernon,
Barry,
St. Clair,
Bollinger,
Wayne,
Butler,
Mercer,
Grundy,
Linn,
Cape Girardeau,
Scott,
Maries,
Dent,
Caldwell,
Webster,

Mississippi,
Madison,
Atchison,
Schuyler,
Sullivan,
Shelby,
Chariton,
Clay,
Bates,
Jasper,
Marion,
Callaway,
St. Charles,
Miller,
Crawford,
Ste. Genevieve,
Stoddard,
Iron,
Nodaway,
Holt,
Cedar,
Moniteau,
Howell,
Ripley,
Audrain,
Ralls,
Montgomery,
Cooper,
Gasconade,
Franklin,
Randolph,
Ray,
Cass,
Barton,
Lawrence,
Henry,
Polk,
Wright,
Oregon,
Carter,
Newton,
Monroe,
Howard,
Christian,
Greene,
St. Francois.
St. Louis,
Lafayette,
Cole,
Stone.

These, together with the 14 counties examined during the year 1890, make 94 in all. These counties are all designated as having been examined for clays on the accompanying map.

Prof. Wheeler's experimental work has consisted of tests of various samples of clays for plasticity, shrinkage and refractory qualities. Up to the present date he has completed and submitted reports of his examinations of 58 samples of clay, of which work perhaps half was done during the year 1891, and the balance during 1890. Since the beginning of 1892, 72 additional working samples have been collected, of which 47 have been ground, preparatory to making complete physical examinations.

As supplementary to the experimental work on the clays, chemical analyses have been made of 88 samples. These analyses were partly made in the laboratory of the Survey by Mr. A. E. Woodward during the year 1890 and the early portion of the year 1891, in part of which work he was assisted by J. D. Robertson. Since April of 1891 this part of the work on the clays has been done in the laboratory of the St. Louis Sampling and Testing Works. During the past two years there have been made, in all, 55 analyses of such clays.

The investigation of the clay deposits of the State constitutes one of the most important branches of the Survey work, and the interruption in its progress during the past two years was greatly to be deplored. Under Prof. Wheeler's energetic direction rapid advance is now being made, however. The work is designed to result in a complete report on the clay deposits of the State, in which will be outlined the distribution of the various clays, and which will contain descriptions of the conditions of occurrence of each important deposit. It is to include the results of searching chemical and experimental examination, which will give an exact measure of the qualities of the various materials, and will designate their special adaptabilities. It will include a review of the clay industry of the State, and will be accompanied by recommendations in the direction of its future growth and development. It is the present hope and intention of the State Geologist to have this work pushed with vigor toward an early completion.

4. EXAMINATION OF THE BUILDING STONES.

The examination of building stones was also in charge of Mr. G. E. Ladd, assistant geologist. During the past year, however, little was done on this subject. In some of the counties enumerated as having been visited in connection with the clay work, examinations of the stone quarries were also made by Mr. Ladd. Since his connection with this Survey was severed, Prof. Hiram Phillips of the State University has continued this work. Owing to the many more urgent demands upon the resources of the Survey, very little money could be allotted to this work, and Prof. Phillips has done little more than collect data as to the location and extent of the quarries in the State, supplementing this by occasional visits incidental to other professional work.

Exact knowledge concerning the building stones of the State is a desideratum abundantly appreciated by the State Geologist, and it is his intention to have this work resumed as soon as the means of the Survey will permit. It is desirable that such investigation shall be wider in scope and of a more exhaustive nature than had been contemplated in the past. It is particularly to be desired that a series of tests should be prosecuted on the most important representative stones of the State, to determine their crushing strength, their resistance to frost action, their resistance to attrition, their resistance to fire and their other qualities which affect the value of a stone. For assistance in this work the use of the testing machine of the State University at Columbia was tendered, and, had the disastrous fire not occurred, it was hoped that circumstances would have permitted the acceptance of this generous offer. It is the intention to place some one in charge of this special work, and not to combine it with the clay work as was done before. It is estimated that, for a thorough test, as many as 50 specimens will have to be prepared from each quarry, and not less than 10 of these should be subjected to each test, in order that a reliable average may be obtained. It will thus be appreciated that the work is one of considerable magnitude, and one requiring the application of skilled and scientific methods.

5. THE EXAMINATION OF THE MINERAL WATERS.

The examination of the mineral waters of the State was originally in charge of Mr. A. E. Woodward, assistant geologist. Mr. Woodward resigned in March of 1891, and since that time the work has been in charge of Prof. Paul Schweitzer of the State University at Columbia.

During the year 1890 Mr. Woodward visited and collected samples from 53 localities in the State, distributed over 31 counties. Of these waters he analyzed 47 during that year. During the first months of 1891 he analyzed about 12 additional waters, with the assistance of Mr. J. D. Robertson.

Since Mr. Woodward's resignation, the mineral water localities have been visited in 16 of the following counties by Mr. Robertson:

St. Louis,
Madison,
Barry,
Vernon,
Benton,
Jackson,
Henry,
Jefferson,
Newton,
Camden,
Morgan
Saline,
Cedar,
Perry,
Howell,
McDonald,
Laclede,
Pettis,
Howard,
Cass.

In these counties about 80 springs have been visited and samples of water for analysis have been collected from a large number. Since that time some 36 analyses of waters have been made by Prof. Schweitzer and other partial analyses and special tests. Thus, very nearly 50 analyses have been made during the years 1891 and 1892. In addition, Prof. Schweitzer has personally visited seven of the important mineral water localities during the past year, and has made careful inquiry into the medicinal properties of the waters, and collected other data of value for his report.

I am glad to be able to say that the Report on the Mineral Waters of the State, a volume of some 280 pages, is now printed. It will be ready for distribution early this month. The completion of this work is due almost entirely to Prof. Schweitzer's earnest efforts during the past two years. Owing to the fact of Mr. Woodward's sad and untimely death, in September, 1891, the opportunity was lost for him to prepare for final publication the results of his work on the subject of the mineral waters of the State. Hence his notes had to be turned over to Prof. Schweitzer in a somewhat fragmentary condition. To these, with the additional material supplied from Mr. Robertson's field observations, Prof. Schweitzer has added the results of his own work, which included not only the analysis of the samples sent him by the Survey and the results of his recent visits in the interests of the Survey, but, further, the results of his many years' previous experience with the mineral waters of the State.

The report includes, in addition to a systematic description of the mineral waters of the State, a discussion of the origin of such waters, of their composition, of the methods of analysis and of their therapeutic values.

6. THE EXAMINATION OF THE ZINC AND LEAD DEPOSITS.

In view of the fact that the zinc and lead deposits of the State were being especially studied by the U. S. Geological Survey, through Dr. Jenney, the State Survey had not undertaken an investigation along the same lines up to the year 1892, but has endeavored to supplement Dr. Jenney's work by inspections and examinations at points in the State not reached by Dr. Jenney, and by collecting full notes for descriptions of all the noteworthy occurrences of lead and zinc ore in the State.

For this purpose, Mr. Robertson of the State Survey, who was formerly detailed to assist Dr. Jenney in his work, made inspection during the year 1891 in the following 38 counties, under the immediate direction of the State Geologist:

Polk,
Dade,
Lawrence,
Newton,
McDonald,
Barry,
Stone,
Greene,
Christian,
Taney,
Douglas,
Webster,
Wright,
Howell,
Texas,
Reynolds,
Oregon,
Carter,
Ripley,
Bollinger,
Cape Girardeau,
Madison,
St. Francois,
Jefferson,
Washington,
Franklin,
Crawford,
Phelps,
Maries,
Osage,
Miller,
Cole,
Morgan,
Camden,
Hickory,
Benton,
Laclede,
Pettis.

These are designated on the accompanying map. In these inspections Mr. Robertson collected notes descriptive of the occurences of the ore at various points, and of the conditions of development. He also collected a large amount of material relating to the past history of mining and to the production of ore at the different mines.

In further prosecution of this subject, certain further and more detailed studies were conducted during the past year by the State Geologist, assisted by Mr. Robertson, in the districts which this preliminary work indicated as most important. This special work was applied in Jasper, Newton, Lawrence, Madison, Perry, Ste. Genevieve, St. Francois, Jefferson and Washington counties. In addition, detailed surveys have been made for the preparation of two sheets of topographic and geologic maps in Jasper and Newton counties, and one in St. Francois, Jefferson and Washington counties. The report on these ores has been written in part, and work will be continued on it uninterruptedly from this date on.

Dr. Jenney's work in the field has been completed over a year, but the State Geologist has not yet received any definite information as to how soon the outcoming report may be expected. Further, Dr. Jenney's work in the State was principally directed toward determining the source and mode of origin of the zinc and lead ores, and his work has been concentrated upon the southwestern portion of the State, where developments permit most thorough examination. It is to be expected, therefore, that his report will not contain so comprehensive a description of the occurrences of the ores in the State as is desirable. The results of the work of the State Survey during the past two years are calculated to compensate for this.

The inability of the Survey to publish as yet a report on the zinc and lead deposits of the State is regretted by none more than by the State Geologist. Unavoidable complications, as already indicated, have, however, caused this delay. It was at one time thought advisable to push the publication of this report ahead of others which were in a more advanced stage of completion, but, as this would have necessitated the preparation of a very preliminary and incomplete report, the idea was abandoned on further consideration. The zinc and lead ores of Missouri are her most prominent mineral products, and they deserve elaborate and comprehensive treatment. The report on these ores should be second to none published by the Survey, and it is the aim of the State Geologist to make it such. These reports are different from those issued by other departments of the State government; they are not annual reports or reports of progress, to be superseded in large part by the volume of the next succeeding year. They are descriptions of natural features and natural occurrences which are to serve as the sole authoritative works of reference for many years to come. Hence it is always to be deplored when any such report has to be hurriedly prepared and rushed into print. A year or so of time thus saved may cause a sacrifice in matter and character of a report which will be a standing regret to both reader and publisher for decades. Therefore, premature publication is an evil or danger to be feared and opposed.

7. THE REVIEW OF THE METALLURGY OF LEAD.

As a supplement to the work on the zinc and lead ores of the State, an investigation of the processes of lead smelting practiced in the State was begun during the latter part of the past summer. The work was placed in charge of Mr. Arthur Thacher, of the St. Louis Sampling and Testing Works. Owing to other duties and engagements Mr. Thacher has, up to the present date, been able to give very little time to this investigation. His examinations so far have been confined to the lead furnaces of St. Francois and Jefferson counties. His work will have been extended to the furnaces of the entire State, however, by the time the report on the zinc and lead deposit is completed, and will be added to that report. So little is generally known of the details of the process and cost of the manufacture of lead from Missouri ores, that Mr. Thacher's results will be of great value to all interested in the lead mining of the State.

8. THE WORK ON PALEONTOLOGY.

The paleontological work of the Survey during the past two years has been in charge of Mr. Charles R. Keyes, paleontologist. Mr. Keyes was appointed to his position about the middle of March, 1891. He had formerly been associated with Mr. Wachsmuth of Des Moines, Iowa, in the preparation of his work on North American Crinoids. He is the author of numerous publications on paleontological subjects, and enjoys the reputation of being a man of great promise in his special line of work.

Mr. Keyes began at once after his appointment upon the preparation of a report on the paleontology of the State, and has been continuously engaged on this work ever since. The object of this report is to satisfy in part a demand by the teachers and citizens of the State for a hand-book on its fossils; 2d, to bring together material scattered widely in literature pertaining to Missouri paleontology; 3d, to set forth our present knowledge on the subject as completely as possible; and, 4th, to prepare a foundation for more extensive faunal studies leading to a proper comprehension of Missouri stratigraphy.

In connection with this work, sections have been examined and collections made by Mr. Keyes and his assistants, over and above what have been collected by other members of the Survey, in Cape Girardeau, Ste. Genevieve, Madison, St. Francois, St. Louis, Lewis, Clark, Jackson, Marion, Pike, Lincoln, Lafayette, Saline, Cooper, Phelps, Dent, Texas, Douglas, Webster, Christian, Greene, Lawrence, Newton, Jasper, St. Clair and Polk counties. In addition, collections have been studied in St. Louis, Hannibal, Sedalia, Columbia, Kansas City, Curryville, Clinton and Springfield, Mo., in Chester and Sparta, Ill., in Burlington, Tabor and Des Moines, Ia., in Washington, Baltimore, Ithaca and New York City.

During the autumn and winter of 1891 and 1892 Mr. Keyes prosecuted his work in Baltimore, along with his studies at the Johns Hopkins University, and he has there availed himself of all the excellent opportunities for consultation of libraries and collections and for interview with specialists in his line of work. Since last spring he has supplemented his work in the office by several trips into the field. During both field seasons he has been assisted by Prof. R. R. Rowley, formerly of Curryville.

The report is designed to consist of about 500 printed pages and to be accompanied by about 50 plates of illustration. The plan is to illustrate one of the leading species of each Missouri genus, and also every species that has been found in the State, but which has never been figured. With all other species abundant reference will be made to publications where good descriptions and figures can be found. In the descriptions the leading species of each genus will be fully treated, but the descriptions of the other members will be made very brief and comparative. In addition, with each species, will be given the horizon and principal localities in the State of its occurrence, with geological and zoological observations upon the structure and relations of each form. Mr. J. C. McConnell, of Washington, and Mr. M. Westergren, of Cambridge, have made the drawings for the plates, they being perhaps the best artists in this line in the country.

The preparation of this report has already progressed far. About 1000 pages of manuscript have been written, which are the equivalent of about 500 pages of printed matter. The drawings for 45 plates are already finished, in a most admirable manner, including about 500 figures. In addition, 8 photo-plates have been prepared. Mr. Keyes' aim is to make the work one of the highest excellence, both as to material and manner in which it shall be prepared and presented. He has displayed great energy and a thorough knowledge of his work in the progress up to present date, and we may feel confident that the outcoming report will be one of great value. The anticipation is that it will be completed and ready for the printer by the end of the current winter.

9. THE EXAMINATION OF THE CRYSTALLINE ROCKS.

This work has continued in charge of Prof. Erasmus Haworth, who has prosecuted the work of mapping the areas of these rocks in the southeastern part of the State, and of studying them microscopically and chemically in the office. In this work he has been assisted during the past two years by Mr. E. H. Lonsdale, assistant of the Survey, and during the summer of 1892 by Mr. M. Z. Kirk, a volunteer aid. During the past two seasons of work in the field, Mr. Haworth outlined the areas of the crystalline rocks in some 400 square miles, and Messrs. Lonsdale and Kirk examined a large territory in Washington, Reynolds, Shannon, Carter, Wayne, Iron, Madison and Ste. Genevieve counties, for the purpose of locating and defining outlying and isolated occurrences.

As a partial outcome of Mr. Haworth's work, there was published during the year 1891, in Bulletin No. 5, a discussion by Mr. Haworth on the age and origin of the crystalline rocks of the State. Between his periods of field work in the summers, Mr. Haworth has continued petrographic studies in the office and laboratory, in preparation for his reports. He has, in addition, written reports on the crystalline rocks of the Iron Mountain and Mine LaMotte sheets, and he has, further, nearly completed a general report upon the crystalline rocks of the whole State. .This report will include a definition of the occurrences of these rocks, and will be accompanied by a map showing their exact distribution. It will include a discussion of the petrography and mineralogy of the areas, embracing the results of microscopic and chemical examinations.

Mr. Haworth has pushed his work with great energy and zeal, and at very small remuneration. The number of years and the studious attention which he has devoted to this subject in the State qualifies him above all others for this study, and we look forward toward obtaining a valuable and exhaustive report from him.

10. THE EXAMINATION OF THE QUATERNARY DEPOSITS.

The systematic examination of the Quaternary deposits was begun during the summer of 1891 by Prof. J. E. Todd. Prof. Todd had previously been associated with Prof. T. C. Chamberlin in the study of the same formations in Nebraska and other northwestern states. He is well known as a careful and conscientious observer, and one thoroughly familiar with the subject of work. Mr. Todd has spent in all about four months' time in the field in the State. During the first summer he made examinations in Marion, Ralls, Pike, Lincoln, St. Charles, St. Louis, Cole, Chariton, Saline, Lafayette, Jackson, Clay, Livingston, Daviess, Buchanan, Nodaway and other counties tributary to the Missouri river, and north of that stream. His work has consisted of a reconnoissance to determine the general character, succession and distribution of the Quaternary deposits in Missouri, including such materials as soils, earths, gravels, etc.—in short, all the unconsolidated formations generally, which lie above bed-rock. We have at present only a general knowledge concerning these materials in the State, and the great advance in our understanding of superficial geology during the last 20 years has rendered it important that detailed examinations should be made from the point of view of recent discoveries elsewhere. Mr. Todd continued his work during the past summer, and extended it into Macon, Randolph, Ray, Howard, Johnson, Boone, Callaway, Montgomery, Warren, Gasconade, Franklin and Jefferson counties. He gave especial attention to tracing the margins of the Glacial drift and loess across the State. A feature of his work that recommends itself as of direct economic value is a definition of the location and distribution of the preglacial channels in the State. These very often restrict materially the distribution of coal in various counties, and they are often valuable as sources of water supply.

As a final outcome of Mr. Todd's work, we plan to have, in the end, a comprehensive report on the Quaternary of the State; but this we cannot hope to have prepared as a result of only four months of field work. Mr. Todd has already transmitted an outline of the results of his observations to date, which can be published as a bulletin if deemed advisable. He further has prepared brief reports to describe the Quaternary deposits in the areas of the Higginsville and Bevier sheets, one of which has been published by the Survey; other such parts of his results will be published in the reports accompanying future sheets. Mr. Todd has prosecuted his work energetically and wisely, and the results which he has already reached vastly exceed in value the amount that the Survey is able to allow for his work.

11. THE WORK OF DETAILED MAPPING.

Detailed mapping was begun during the year 1891 by two parties, one in charge of Mr. C. F. Marbut, with Mr. M. C. Shelton and Mr. T. B. Marbut as aids; the other in charge of Mr. E. H. Lonsdale, with Mr. Emil Theilman and later with Mr. E. M. Johnson as aids.

Mr. Marbut and party prosecuted work continuously during the season in Ray, Randolph, Chariton, Macon and Henry counties. They covered in all an area sufficient for four of the Survey sheets, or nearly 1000 square miles. The successful results of this party's summer's work is almost entirely due to the ardor and energy with which Mr. Marbut, who was in charge, has pushed the work. Mr. Marbut came to the Survey during the year 1890, and he has applied himself to the mastery of his work so intelligently and perseveringly that he is now able to assume independent charge in a highly efficient manner.

Mr. Lonsdale and party began work in Madison county, but owing to Mr. Johnson's, and later to Mr. Theilman's resignation, and later again to the severe illness of Mr. Lonsdale, this work was so interrupted that only an area sufficient to complete one more of the Survey sheets was covered, or about 160 square miles. Mr. Lonsdale applied himself earnestly to his duties, and, could he have retained efficient assistance and had his health remained good, two or perhaps three sheets in this region would have been completed.

During the field season of 1892 only one such party was organized, with Mr. C. F. Marbut in charge, assisted by Mr. T. B. Marbut during the entire season, and by Mr. E. H. Lonsdale during the latter part. One and two-thirds sheets were covered in Jasper and Newton counties, including about 300 square miles, and another sheet in St. Francois and Washington counties of about 230 square miles.

In addition to these recent results of the detailed mapping, other work of a similar nature has been done over the areas of the preceding year's work, and, further, additional leveling has been necessary in order to correct errors which were discovered, resulting from faulty control in Johnson and Lafayette counties. This work was prosecuted by Mr. Leo Gluck, assistant. Further, mapping was prosecuted in Polk county by Major E. W. Newton, local assistant, and over 200 square miles of topographic and geologic mapping has been done. Major Newton's experience as a topographical engineer during the late war has well fitted him for the topographical part of this work, and his minute knowledge of the lithology and geology of the country about Bolivar, his residence, enabled him to accomplish the geologic part of the work in a more complete manner than it is possible for the Survey to undertake in similar sections of the State which are not of prominent economic importance. Major Newton's association with the Survey is an instance of a plan of co-operation between the Survey and individuals of the State, which it is desirable that there should be more of. It is to the interests of the Survey as well as those of the State at large, that the study of its geology should be fostered among its citizens; that they should grow to have more interest in the results we are trying to reach; that they should recognize the desirablity of mastering the details of their local geology. In this they should receive the assistance of the State Survey, and, on the other hand, the State should acquire the results of their work. It is to be desired and is probable that similar co-operation can be arranged for in the future in other sections of the State.

Summarizing the above, there has been mapped during the past year in:

	Sq. miles.
Randolph, Macon and Chariton counties	240
Ray	230
Madison, St. Francois, Ste. Genevieve, Washington and Jefferson	400
Henry and Benton	460
Jasper and Newton	400
Polk	230
Total	1,960

These, added to the 1574 square miles mapped during 1891, make a total of over 3500 square miles, embracing 14 sheets, of which field work is completed to date.

One of these maps, the "Higginsville Sheet," and the accompanying section sheet and report have been published; two others have been engraved, and the accompanying reports have been written and could be published this winter. Other reports, which will be published with the various sheets, are also in course of preparation. The results so far reached by these maps demonstrate that the expectations concerning the value of this work were in every way justifiable. These maps of important areas of the State, with the accompanying reports, we feel no hesitancy in saying, will stand in future among the most substantial productions of the Survey's work and will rank among its monuments.

12. GENERAL GEOLOGICAL MAPPING.

Under this head is included such work as is specially designed to display on a map the distribution of the different geological formations of the State. All the field work of the Survey is contributory to this end; but where the definition of the formations is not plain, or where the stratigraphy is intricate, special work for this purpose has to be done. Under such heading may be included the work done by Prof. Haworth and Mr. Lonsdale during the past years in the southeastern portion of the State, for the purpose of outlining the crystalline rocks of that section. Here such work was done over a territory of several thousand square miles.

In Greene county similar work has been prosecuted by Prof. E. M. Shepard, of Drury College, who has worked as local assistant in the vicinity of Springfield. During the past years he has mapped the distribution of formations over an area of about 800 square miles, and has collected a large number of fossils from the area of his work. He has, further, prepared and transmitted a report on this area.

13. THE MINOR SUBJECTS OF WORK.

The minor subjects of work which have engaged the attention of the members of the Survey during the past year were enumerated on page 5.

Mr. Marbut's statistical and historical work includes a large amount of material relating to the production of minerals in the State. In this connection he has obtained from railroad companies, from mine operators, from furnace managers and from many dealers in ores and other private individuals, information relating to the productions and shipments at different periods and the value of the productions at different dates. That Missouri has been a producer of mineral substances for a large number of years we all know, but we have no very definite idea as to how much ore has been produced and as to the economic conditions which, at any special time, caused it to be large or small. It is desirable that we should know exactly under what conditions Missouri's products are most available and when their development will yield the best returns. The consideration of the experience of the past will help us to this end. This work which Mr. Marbut has taken up, somewhat as a side issue, will be of undoubted value in this direction. The results will be incorporated in the several reports of the Survey relating to the special subjects.

The Hypsometry of the State is a subject which has never received exact investigation. The elevations of different points in the State are only approximately determined, and the distribution of the zones of equal altitudes are not defined. In connection with the detailed mapping of the Survey, it becomes necessary that we should know, with reasonable exactness, the *relative* elevations, at least, of various points in the State which are included within the areas mapped. The datum to which all such elevations are referred is the "mean sea level." The primary base lines are the lines of precise leveling of the Mississippi and Missouri River Commissions, along the respective streams, and the trans-continental line of the U. S. Coast and Geodetic Survey which traverses the State. Our secondary base lines are the lines of leveling for the various railways, where constructed or surveyed throughout the State, as embodied in their profiles or level books. As the methods by which railroad leveling is done are far less exact than the precise leveling of the Government Surveys errors in the determinant of altitudes frequently occur, and, in order that their results may be used, the errors must be detected and eliminated. For these purposes, profiles or lists of elevations along all the various railroads in the State have been obtained. These will be compared at their intersections, and any discrepancies which are detected will be inquired into and corrected. When this is done, and all the various lines are adjusted, we shall have a net-work of lines of level throughout the State upon which we can base our mapping with reasonable confidence. It is proposed to issue a report in which shall be embodied a list of elevations along all the various railways, and a map which shall be what is known as a Hypsometric map, or one showing the distribution of different zones of altitude in the State. This report and map are necessary for the work of the Survey, for reasons above given. It is, further, invaluable for many other scientific purposes, as well as for the every-day uses of the engineer and business man. Mr. Leo Gluck, assistant, has given a part of his time during the year 1891 to collecting the necessary material for this report, and to preparing it for comparative study.

In addition to the detailed mapping referred to on pages 18 and 19, mapping has been done in still greater detail at a few localities for the purpose of constructing models to illustrate the conditions and modes of occurrence of various minerals of economic value. These surveys have been made by Mr. C. F. Marbut and by Mr. Leo Gluck.

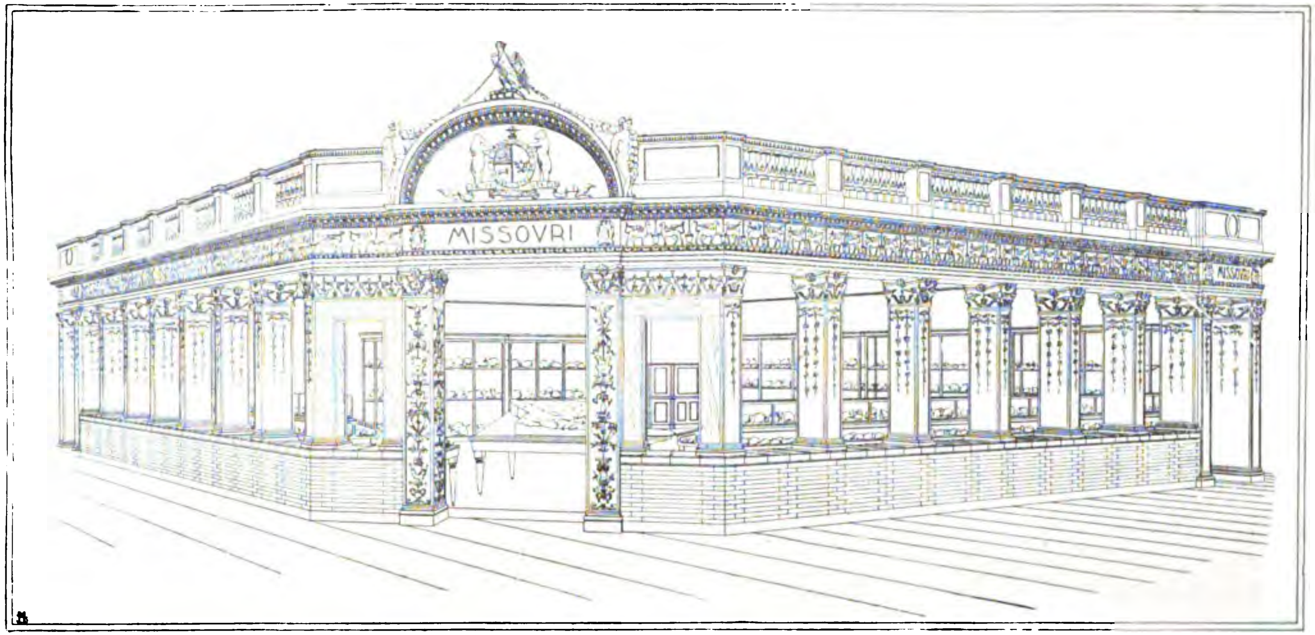
Models are recognized as being among the most efficient agents for properly displaying and illustrating natural phenomena, and it is the plan of the Survey to have a series of such models constructed, in order to bring clearly to the understanding of others matters of importance and interest in the geology of the State. The educational function of the Survey is well subserved through this means, and the recognition of this function is of first importance.

The Collections.—During the past two years some 2500 specimens have been added to the Survey collection, the larger portion of which have been examined or labeled and filed away for future study and use. A large number of these have been prepared and have been mounted and are now on exhibition in the Survey cabinet. This has been the special duty of Mr. J. D. Robertson, and he has displayed much taste in the display of the specimens, and has attended to the cataloguing with praiseworthy care. The collections of the Survey now number about 5000 specimens. It is probable that the supply of material will soon be sufficient for the Survey to be able to act upon the suggestion of section 7 of the act controlling it, which provides for the furnishing of collections to colleges and public museums in the State. It is recommended that, as soon as the Survey collection will warrant it, an educational series of specimens be prepared for distribution among the institutions of learning in the State at the nominal expense to such institutions as provided for in the act. This will open another field of usefulness for the Survey, and will enable the various institutions to obtain representative collections at a very small cost.

For purposes of illustration there have been taken during the past year about 200 photographs. These are used in preparing cuts and drawings for illustrating reports, and are further used for exhibition in the Survey museum.

The World's Fair Exhibit.—The Thirty-sixth General Assembly appropriated $150,000 for the purposes of Missouri's display at the World's Fair. Of this, the sum of $15,000 was set aside for the collection, preparation, installation and care of the Mineral Exhibit. The immediate direction of this work was placed in charge of the State Geologist by the Missouri World's Fair Commissioners, through the chairman of the committee on mines, Col. H. H. Gregg, and their executive commissioner, Mr. J. K. Gwynn. General plans and estimates for

MISSOURI MINERAL EXHIBIT.



General View of the Exterior of the Missouri Mineral Exhibit at the World's Fair.

the exhibit were submitted by the State Geologist, and he appointed Dr. E. O. Hovey superintendent of the exhibit. Dr. Hovey began work last July, and has since applied himself industriously to the gathering of specimens and to the preparation of detailed plans for the exhibit. The energy and skill which he has displayed in this work, combined with his knowledge of the related subjects, have proved him to be the right man for the place. In the collection of specimens from Jasper and Newton and adjoining counties, effective assistance has been rendered by Mr. J. A. Reeves of Joplin, who was assigned that district to work in. Similarly, Mr. Joseph E. Cobb of Springfield, Sec. of the Springfield Mining Bureau, has done much to advance the interests of the exhibit in his section. From the collections of the Survey, eight large boxes of specimens have already been packed for shipment to Chicago, and others will be contributed later. In all, about 200 boxes of material are now ready.

Missouri has been assigned by Mr. F. J. V. Skiff, Chief of the Department of Mines and Mining, one of the most prominent locations in the Mines and Mining building. It is in the center of the building, at the intersection of the two grand aisles, with Michigan, Germany and Great Britain occupying the three other corners.

This assignment has been undoubtedly because of the great interest which Missouri has shown in the prospective World's Fair, as evidenced by the liberal appropriation made, and because of the activity of the World's Fair Commission and others in caring for the interests of the State and in formulating plans for the exhibit, which could not but meet with the hearty approval of the management at Chicago. In recognition of the fact that this prominence of the State at the World's Fair adds additional responsibility, every effort is being made to prepare and install the exhibit in such a way that it will be lasting credit to the State, and will in no way cause the slightest disappointment to those who have thus placed confidence in its resources, and in the capabilities of those who have the work in charge.

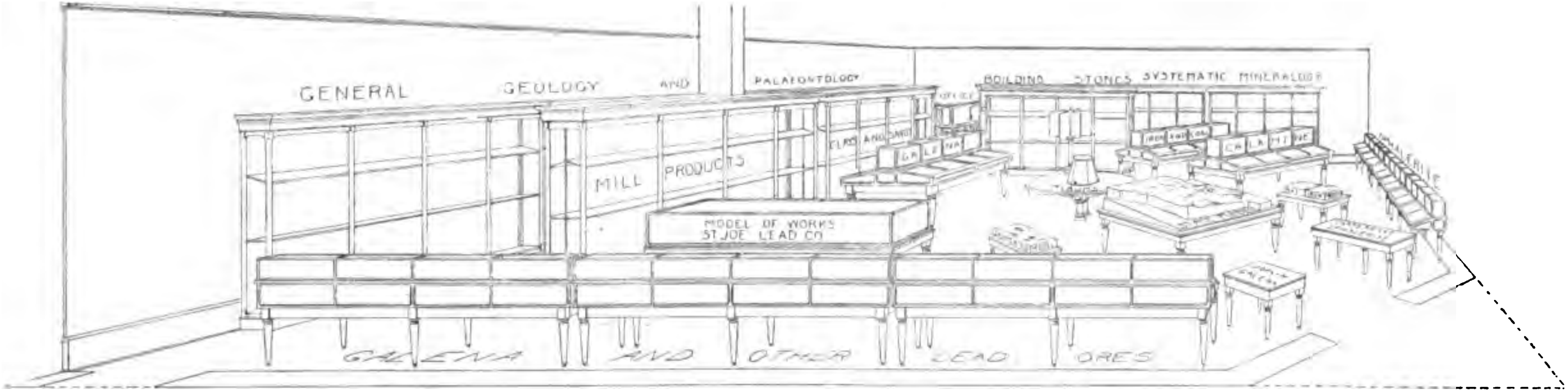
The figure of the plate opposite this page illustrates the exterior view of the enclosure of the exhibit. The handsome central entrance and colonnade along the sides are to be composed largely of Missouri building materials. The base is of granite from southeastern Missouri; the wall is of brick from St. Louis county, and the pillars and capitals are of Missouri terra cotta. Inside of this enclosure are polished oak, glass-covered cases and tables. In and upon these will be arranged the material for display. These will include large numbers of handsome specimens, all carefully labeled as to name and place; a large number of photographs illustrating different mineral localities, mines and physiographic features of the State, together with maps and diagrams showing the production of minerals, their distribution and their modes of occurrence. A particularly interesting feature of the exhibit will be a series of models displaying different sections of the State and different important mineral deposits. Among these will be a large model of the whole State, about six feet square, showing the topography in relief, the areas of the geological formations and the location of the zinc and lead, iron, coal, clay, copper and onyx deposits, building stones and mineral waters. There is every reason to expect that the display will be fully up to the requirements demanded by the occasion as specified by the writer in the recommendations of his biennial report to the Thirty-sixth General Assembly.

14. THE WORK IN THE OFFICE.

Publications.—During the past two years there have been printed and issued from the Survey office Bulletins No. 3, No. 4 and No. 5, the Biennial Report of the State Geologist for the years 1889 and 1890, a Preliminary Report upon the Coal Deposits of the State, and the Higginsville Sheet and Reports. In addition, there have been written, and are now printed, a Report upon the Iron Ores of the State, a Report upon the Mineral Waters of the State. A Report upon the Bevier Sheet in Macon and Randolph counties, with accompanying maps and sections, is ready for the printer, but has not been transmitted on account of the exhaustion of the appropriation. We may thus consider as having been published by the Survey during the years 1891 and 1892, the following reports:

	Octavo pages.
Bulletin No. 3	101
Bulletin No. 4	40
Bulletin No. 5	87
Biennial Report of the State Geologist	53
Preliminary Report on Coal	226
Higginsville Sheets and Report (18 pages, large folio), about	100
Report on Iron Ores, about	400
Report on Mineral Waters, about	290
Bevier Sheets and Reports (ready for the printer)	60
Total	1357

MISSOURI MINERAL EXHIBIT.



VIEW OF INTERIOR OF THE MISSOURI MINERAL EXHIBIT AT THE WORLD'S FAIR.

During the year 1890 there were published—

	Octavo pages.
Bulletin No. 1	85
Bulletin No. 2	158
Grand total to date	1600

In addition to the above, the Report on the Paleontology of the State is nearly entirely written, and will comprise a volume of about 500 printed pages and 50 pages of plates. The Report on the Crystalline Rocks is also nearly completed. The Iron Mountain Sheet has been, engraved and the accompanying report is about ready for the printer. A Report upon the Springfield Sheet is written, and the Reports upon the Warrensburg and Mine LaMotte Sheets are partially prepared. About 100 pages of the Report upon the Zinc and Lead deposits have been written. The formal preparation of the Report on Clays is not yet begun, but a large bulk of notes has been collected and results have been tabulated; the same may be said concerning the smaller report on the Quaternary Geology of the State.

Further, there have been platted ready for the engraver the following 12 sheets of detailed maps, as well as the section sheets accompanying all except the ninth and tenth :

1. The Lexington Sheet in Lafayette county.
2. The Warrensburg Sheet in Johnson county.
3. The Huntsville Sheet in Randolph county.
4. The Mine La Motte Sheet in Madison county.
5. The Bevier Sheet (engraved) in Macon county.
6. The Richmond Sheet in Ray county.
7. The Clinton Sheet in Henry county.
8. The Calhoun Sheet in Henry county.
9. The Carthage Sheet in Jasper county.
10. The Joplin Sheet in Jasper county.
11. The Higginsville Sheet (engraved) in Lafayette county.
12. The Iron Mountain Sheet (engraved) in Iron county.

The sections for the ninth and tenth sheets and the Bonne Terre sheet, in St. Francois county, will be drawn this winter. The drafting of these maps and sections has been done by all the various members of the Survey who conducted the work in the field, and, chiefly, under the direction of Mr. C. F. Marbut.

The Editorial Work.—The editorial work of the Survey has been conducted by the State Geologist, assisted, in part, by Mr. Robertson. This has included the revision of the original manuscript, the selection and supervision of the illustrations, the revision and correction of proof, etc. The amount of time consumed by this work can be conjectured only by one who has endeavored to execute it in a critical and painstaking manner. The embarrassments of the task can be imagined by all who know anything of the inherent sensitiveness of an author concerning his productions. It is a creditless occupation. In this connection, however, the State Geologist wishes to express his gratitude for and appreciation of the courteous and willing manner in which the members of the Survey have accepted criticisms and suggestions concerning their writings, and this especially to Mr. Nason and Prof. Schweitzer, the authors of the two volumes issued this year.

The attendant general office work of the Survey during the past two years has been very heavy. The various reports which have been issued had to be distributed, which is in itself no small work, and has involved the writing of thousands of addresses and the mailing of a corresponding number of copies of publications. Of the publications that have been prepared and issued by the Survey, there are now left for the purposes of distribution the following numbers:

Bulletin No. 1. Biennial Report of the State Geologist for 1889 and 1890. Out of print.	
Bulletin No. 2	234
Bulletin No. 3	375
Bulletin No. 4	528
Bulletin No. 5	432
Preliminary Report on Coal	3,019
Higginsville Sheet and Report	1,398

Of the 1398 copies of the Higginsville Sheet, 500 copies are reserved for the final edition of a State Atlas, after all of the sheets of detailed maps are engraved and printed.

Distribution of Reports.—The practice has been heretofore to distribute these publications to all who applied for them, and to all whom we thought would be interested in receiving and having them. The postage has generally been prepaid on such issues; but, at the time of the exhaustion of our funds of 1889, it was necessary to require that stamps be sent in order that we should not overdraw our appropriation. The general guiding principle has been that reports be sent to those only who need them and who will make proper use of them. An indiscriminate distribution will exhaust the supply very quickly, and those who are in need of the reports in the future will not be able to obtain them and the best interests of the State will not be subserved. To control their distribution two methods suggested themselves. A small price could have been fixed on each report, at which it would be furnished those who do not exchange publications with the Survey and whose official position does not entitle them to their receipt gratuitously. This would have involved, perhaps, some special legislation, and would further have necessitated the preparation of a classified mailing list. Another mode of controlling the distribution of the reports is to prepay postage only to officials specially entitled to them, to those interested in the results with whom we exchange publications, and to those to whom we are otherwise under obligations, and to require the payment of postage from all others. This was the most practical plan, and was adopted during the past year. The cost of mailing the publication of a volume of several thousand is, in itself, a very considerable item. At 25 cents a copy for 3000 copies it would alone amount to $750, and when there are several volumes to be distributed at greater cost than this, the attendant expense would seriously cut into our limited publication fund. Still, this is not the main consideration, and does not fully answer the objections raised by some to this plan of distribution. The main object is to prevent the undue waste of these State reports, to distribute them to those who want and need them, to prevent the exhaustion of the edition while the report is still in demand. There are many people who will ask for and take anything if they can get it for nothing; afterward they may sell it or throw it into the waste-paper basket. If a man does not want a report to the extent of a few cents in postage he does not deserve it, is the controlling idea in the present case. In practice it seems a satisfactory principle to follow, and restricts distribution without subjecting the Survey to the charge of favoritism.

Clerical work.—The correspondence has also been quite large during the past two years, and has involved the writing of about 4000 letters, many of which were quite long and have necessitated much consideration and study for their preparation. In addition, the manuscript for the different reports had to be type-written. The distribution of the reports, the keeping of the accounts and other similar office work of the Survey, since the month of April, 1891, has been conducted by the secretary, Miss S. R. Mann, aided, at intervals, by Miss L. H. Mitchell and Miss M. McHenry. The State Geologist feels under obligations to her for the efficient assistance she has rendered in this work.

Determination of specimens.—As has been referred to, a large number of specimens have been sent in to the State Geologist by the citizens of the State for determination, and he has in all cases gladly responded to their inquiries so far as he was able. As has already been published in Bulletin No. 1, however, it is not in the province nor is practicable for the Survey to make analyses or assays of material sent in by outside parties. The principal reasons for this are that we can know nothing authoritatively concerning the origin of such specimens; and, further, if we were to undertake such work gratuitously, we should be so flooded with material that a force of ten chemists could not supply the demand; hence the extent to which examinations are carried is to make a hand inspection of specimens sent in, supplemented at times by a simple chemical or blow-pipe test. The results of this hand examination are sent as such to the applicant with advice, if desired, concerning the advisability of his going to the expense of having the specimen analyzed or not.

Over and above the analytical work cited in the preceding pages, in connection with special subjects of work, Mr. Robertson has conducted 17 analyses of limestones and marbles, 14 analyses of cherts, nine analyses of tallow clays, four of residuary clays and shales, and three of sandstones.

15. ASSISTANCE RENDERED THE SURVEY.

The assistance rendered the Survey through the U. S. Geological Survey in the examination of the zinc and lead deposits has already been referred to on page 13. To the U. S. Coast and Geodetic Survey the Survey is indebted for assistance rendered in the determination of points of latitude and longitude, which are necessary for the prosecution of mapping, and, further, for the resumption of the work of precise leveling across the State which was extended during 1891 from Jefferson City to Kansas City. These works are of great value and probably cost the Coast and Geodetic Survey several thousand dollars.

From citizens of the State and corporations the Survey has received much assistance. Especially to the railroads of the State is the Survey indebted for assistance rendered the State Geologist and other members of the corps over the various lines. To mining companies, operators and private individuals we are under obligations for valuable data furnished, for cordial reception and hospitable treatment.

RECOMMENDATIONS FOR THE FUTURE.

The objects of the Geological Survey, as expressed in the act creating it, are to define the succession, position, distribution and thickness of the various geological formations of the State; to determine the existence and distribution of the many differc [illegible]
rocks, coals, etc.; to note the character of the soils, the growth of timber and other scientific matters that may be of practical importance and interest. Its essential functions are thus to determine facts of occurrence and distribution, facts of qualities and capabilities, as distinguished from facts of production which are gathered by other bureaus of the State government. It is primarily a work of investigation.

The present Geological Survey of the State has been in operation practically only three years; for, although the first appropriation was made early in the year 1889, the State Geologist was not appointed until the autumn of that year, and the work was hardly organized at all before the beginning of 1890.

The total amount expended during this period, including costs of publications, is $60,000. During the past two years there has been expended $3,851.50 of the appropriation of 1889, and $39,990 of the appropriation of 1891.

The distribution of the funds is shown in the following two tables:

EXPENDITURES FROM THE APPROPRIATION OF 1889,

During the Months of January, February and March, 1891.

1. Salaries	$2,229 48
. Railway fares	75 90
3. Subsistence	96 41
4. Postage and telegrams	124 21
5. Freight and expressage	44 06
6. Printing	985 82
7. Office and cabinet furniture	85 92
8. Office and cabinet supplies	44 57
9. Field supplies	102 85
10. Laboratory supplies	23 33
11. Horse and wagon hire	19 88
12. Library	85
13. Engraving and plates	12 22
Total	$3,851 50

EXPENDITURES FROM THE APPROPRIATION OF 1891.

Salaries	$22,285 00
Subsistence	2,300 00
Railway fares	1,077 00
Horse and wagon hire	1,300 00
Postage and telegrams	544 00
Freight and express	521 00
Office furniture	177 00
Office instruments	170 00
Office supplies	235 00
Cabinet furniture	255 00
Cabinet supplies	74 00
Laboratory instruments	4 00
Laboratory supplies	115 00
Field instruments	181 00
Field supplies	285 00
Library, books	75 00
Photographs and supplies	141 00
Reports, copying, printing and distributing	4,860 00
Reports, binding	1,660 00
Maps	1,827 00
Plates	1,158 00
Figures, drawing, etc	391 00
Office printing	146 00
Temporary assistance	211 00
	$39,990 00
Balance	10 00
	$40,000 00

The operations of the Geological Survey up to the present date are detailed in the preceding pages of this report, and the product of those operations is briefly summarized on pages 24 and 25 of the same. To these pages the reader is respectfully referred in this connection.

With the facts above stated, and with the knowledge of what has been said concerning the work of the Survey in the past, we are in a position to outline the work for the future.

The first work which calls for attention is the finishing of *the work on hand.* This includes the completion of the various subject reports enumerated on page 25 and their preparation for publication; it next includes the engraving of the maps and section sheets tabulated on that page and the preparation of the accompanying reports. Much of this work will be done this winter, and by spring it is probable that two or three more reports can be made ready for the printer. The printing of these and the preparation of other reports will continue during the whole of next year.

The second work to claim our attention is that of *new work.* The subjects which have engaged the attention of the Survey in the past have been those of most prominent importance in the mineral industries of the State. There are, however, a number of other subjects which, while relating to matters of minor importance, yet deserve and demand attention. Among these we include limes, cements, onyx, marbles and copper, and also the subject of ore dressing, with especial reference to the more effective concentration of our zinc and lead ores. Further, as already stated on page 49 of the report to the Thirty-sixth General Assembly, agriculture and forestry are made, by law, subjects of work of the Survey, and it is desirable that these subjects receive some attention. Finally, too much attention cannot be laid upon the importance of continuing detailed mapping in different sections of the State. This mapping of the Survey is designed to display, with great minuteness, the topography of the country, the geology and the distribution of minerals. This work has been confined, so far, to only a few portions of the State, but it should be extended to other sections. The economy with which this mapping has been conducted is remarkable, part of it having cost only one-fifth of what such work has cost in other States. For fuller explanation of the nature of this work, the reader is referred to pages 18 to 20 of this report.

Estimates and Appropriations.—To continue the work along the lines indicated, it is hereby recommended that at least the same amount be appropriated for the work of the Geological Survey during the next two years that was appropriated in 1891 by the Thirty-sixth General Assembly, namely, $40,000. It must be remembered, in this connection, that all of the expenses of the Survey are defrayed out of this appropriation, including the heavy item of publications. With most, if not all other State departments, the publications are paid for out of the general fund for public printing. If this were the case with the Geological Survey, the appropriation for the work could be reduced from a quarter to a third. The publications of the Survey are of such a technical character that they could not well be controlled by the

State Commissioners of Public Printing. The provision whereby these publications are provided for out of the Survey appropriation is, therefore, a wise one. The fact must, however, be recognized when comparing the amount appropriated for the Survey with that for the other departments.

We feel no hesitancy in affirming that the work of the Survey has been conducted with remarkable economy, both as to salaries and expenses and cost of publications. The amounts paid the assistants of the Survey and the limits fixed by law for the salaries of the assistant geologists have been very low, and it is only their enthusiasm and interest in their work which retained some of them on the force.

The expenses for the maintenance of the Survey during the next two years will continue fully as great, if not greater, than during the two years past. The appropriation of the past two years was not sufficient to provide for the publication of all that could have been made ready. The amount which can be published will, without doubt, exceed what has been published heretofore; hence a reduction in appropriation cannot be made without seriously crippling the work.

The past product should be in a great measure a control for future support. It is, therefore, with great gratification that we are able to point to the results of the Survey work displayed in the preceding pages. Considering the short time the Survey has been in existence, the great area to be covered, and the comparatively limited means at its disposal, this is a most creditable performance, and will compare favorably with that of any other Survey in the country. The products of the work have already excited the favorable comments of scientific and business men throughout the country.

It is difficult to compare the results of such work by figures, to express the amount or value of the work by dollars and cents. The quantity of the product, especially we are considering publications, is not all by any means; quality must always be considered. With this proviso clearly understood, the following table is introduced. It shows the amounts expended during the various periods by the State of Missouri for her different Geological Surveys; it shows the amount of material published by each of the several organizations, and, from this, the amount expended per page of publications is deduced:*

Period of appropria'n	Am't expended.	Pages published....	Maps and illustrations.	Expenditures per p. publ....
1853 to 1862	$95,200	476	69 illustrations and 5 small county maps.	$200
1870 to 1871	2,500	25	No illustrations.	100
1872 to 1874	72,000	1,909	29 illustrations, 9 small county maps.......... 281 illustrations, one large atlas, 22×28, containing 14 sheets, one small atlas, 13×15, containing 15 sheets	38
1876 to 1877	6,500	200	11 illustrations..............................	33
1889 to 1892	60,000	1,600	291 illustrations, 3 small maps, 2 large maps of State, 2 detailed topographic maps, 2 detailed section sheets........................	38
1853 to 1892	236,200	4,210	Average	57

According to this table, the total amount expended up to and including the year 1876 was $176,200; $196,000 was actually appropriated, but of this amount $19,800 was unexpended and returned to the treasury. In the above table, this unexpended amount has been distributed among the expenditures of the periods of 1853-62 and 1870-71.

From this table it will be seen that the amount expended by the present Survey per page of publication is vastly less than that expended for publications of what is commonly known as the Swallow Survey (1853 to 1862), and is the same as the amount expended during the Pumpelly-Broadhead Survey (1872 to 1874), and these two surveys are the only ones of the past which were of sufficient magnitude to be considered independent organizations. *But it must be remembered that this is by no means all.* The figure of amount expended per page by the present Survey applies only to the publications actually printed. It is necessary that there be credited to the present organization all the unpublished but prepared material enumerated on pages 24 and 25 of this report. This includes the manuscript and illustrations of the Report on Paleontology, the manuscript of the Report on the Crystalline Rocks, the manuscript of the reports on the Iron Mountain, Springfield, Warrensburg and Mine LaMotte sheets, the manuscript of the Zinc and Lead Report, the great amount of work embodied in the notes collected in the field, and in the results of experimental and chemical work in preparation for the clay report, the notes collected and manuscript written on the Quaternary Geology of the State. Further, we must credit this Survey with ten of the maps and accompanying section-sheets given on page 25, which have been surveyed and drawn since its beginning. It will be seen, therefore, that the outcome cannot be considered other than most creditable by any unprejudiced person.

Concerning the large expenditure per page for publication of the Swallow Survey, it is, however, but fair to add that the Civil war is probably largely to blame for this: that is, a great portion of the product of this work must have been ready for publication at that time and remained unnoticed, and probably became in large part lost during the turbulent period which followed. Further, of the reports of 1872 to 1874, one of three hundred and fifty pages was, in whole, or in great part at least, the product of the Swallow Survey before the war, as was also part of one of the other volumes.

Figures were given in the last part of the report to the Thirty-sixth General Assembly, showing that the amount appropriated by Missouri for the maintenance of her Geological Survey was less than that appropriated by other states of equal importance and magnitude. This need not be repeated here. Facts were also introduced to illustrate the relation between the amount appropriated and the great area covered by the State. Suffice it here to say that the sum asked for amounts to only one-twentieth of a cent per acre; to less than one-tenth of one per cent of the value of the annual product of minerals in the State; it represents only one four hundredth part of one per cent of the total assessed valuation of property in the State. It is hence an altogether insignificant item of taxation. The amount asked for is not extravagant; it is altogether moderate. Did the Survey undertake to do all that is wanted and all that is asked of it, there would be need of many times that amount, and we wish to take this opportunity to explain why it is that the Survey cannot satisfy all the demands upon it; that the members cannot be everywhere at the same time; that they cannot exhaustively examine and report upon a great State of nearly 70,000 square miles in the course of a few years.

We have almost daily applications to visit different localities in the State in the interest of different individuals; we have similar applications for analyses and assays; we have frequent expressions of regret, disappointment and resentment from people of greater or less intelligence and influence that these applications are not complied with. The only reply is, that it is absolutely impossible for this to be done with the limited means and limited time at our disposal. We have planned the work of the Survey with the best interests of the State as a whole in mind, and, if the work is allowed to go on, all important localities and subjects will receive due attention. To illustrate the impracticability of some ideas advanced, we would instance the case where resentful expressions appeared, both in local newspapers and in private communications to the writer, because certain iron ore localities in his section had not been visited and had not received sufficient attention, during the prosecution of the work upon iron ores in southern-central Missouri. Now there is, on an average, one outcrop of iron ore on every square mile in a large part of this region. Considering that there are sometimes three or four farms on every square mile, if every man had a right to demand and expect an examination of his individual property, it would take a hard-working geologist just about 22 years to complete, and that in a very rapid manner, such an examination of the area covered by the iron ore work during the past year. If, in his report, this geologist allows only five lines to the description of each deposit, the report on this subject would fill five volumes similar to our Coal Report. Manifestly the work cannot be conducted on the plans conjectured by one who has had no experience in such matters. Neither does his resentment merit serious consideration.

As has already been referred to on page 52 of the Biennial Report to the last Legislature, the life of the Geological Survey of the State during the past years has been very fitful. To quote:

> It has existed for a few years only to be discontinued before any plan of work was completed, and at the sacrifice of much of the result reached. It has been weakened by successive changes of management, with accompanying changes of policy. Its trained corps and its equipment for work have been lost during the interim between two periods of activity. Its collections, designed to illustrate the resources of the State, have been scattered, and with it all a considerable sum of money has been expended. Yet the interests which this work is especially devoted to have continued to exist, and have continued to demand recognition, and will always continue to do so, whether it be through a Bureau of Geology and Mines, through a board of internal improvements, through a bureau of statistics or through a special commission. And these facts, true as regards Missouri, are based upon the experience of other states and nations.

The reasons for such interruptions of work are probably several, but the one which appears to the writer to be the most influential is the fact that the results and the benefits of such work are not attained or realized at once. The reports take several years for their preparation, and are, in many such instances, hardly printed before the work is abolished. It then takes more time for them to reach the proper hands, and it takes still longer for them to be assimilated and for the rules and facts which they impress to be applied to useful ends. It is only then that the full value of the work begins to dawn upon the consciousness of many people; it is only then that expressions of regret begin to be heard that the work was interrupted, that so many results were allowed to go to waste, that so much time has been lost. We then have another bill introduced into the Legislature, and an appropriation made for the inauguration of a new Survey and the resumption of the work, and the ball is started rolling again. The revival of Geological Surveys during the recent years in the states of Texas, Arkansas, Iowa, Georgia and Missouri is, in the writer's opinion, strong evidence in support of the position here maintained. Surely, we should profit by past experience; we should not impair in any way a useful piece of machinery which we have just gotten into good working order.

To quote again from the last Biennial Report:

> Just so surely as it is true that it is conducive to the welfare of the State that the existence, the extent and nature of its mineral resources should be determined and made known, just so surely will such work be prosecuted. History would teach us that the question is not whether these facts shall be determined or not, but whether they shall be determined now or later. If determined now, the results will be available at once and the benefits will be felt immediately; if determined later, the beneficial effects will be deferred in proportion. The work is not to be regarded as a luxury which a rich state may afford, but which a poor state may dispense with; it is an investment which will yield good returns to the poor as well as to the rich; it is a work of improvement which will enhance the value of property; a work in harmony with the peace-loving spirit of the age, in accordance with which the energies of the State are being directed more and more toward industrial development.

The reports are distributed not only in the State, but over the whole of this country, and to foreign countries also. The Survey thus conveys information, first, to the citizen of the State, concerning the resources of his lands and guides him in the determination of values and in the development of his property. Second, it scatters broadcast to the foreigner authoritative knowledge of what is in the State, and interests capital in its development, with a consequent enhancement of values. It is constantly acquiring new facts of interest and importance, and is thus, by degrees, accumulating a vast store of knowledge concerning the natural features and mineral products of the State, which make it a factor of the broadest possible influence in public improvement and industrial development.

Before closing these remarks, I wish, in conclusion, to call especial attention to the Missouri Mineral exhibit at the World's Fair. According to a provision of the law creating the Missouri World's Fair Commission, the larger part of the material of the mineral exhibit will revert to the Bureau of Geology and Mines. It is, therefore, necessary that some provision be made to install and adequately care for this magnificent collection of Missouri's products. No better object-lesson could be prepared to convey an impressive idea of the resources of the State. The opportunity should emphatically not be lost for making this substantial contribution a foundation for a permanent State museum for the exhibition of Missouri's natural products.

Reviewing the progress of the work as outlined by the report, it can fairly be considered creditable. The Survey has now been in operation for a period of three years, and is now entering upon its fourth year of work. The past has been a period of organization and accumulation, and the period of production is now reached. During the coming year we can confidently look forward to a period of even greater productiveness.

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MISSOURI GEOLOGICAL SURVEY.

CHARLES R. KEYES, STATE GEOLOGIST.

BIENNIAL REPORT

1893-94

OF THE

STATE GEOLOGIST

TRANSMITTED BY THE

BUREAU OF GEOLOGY AND MINES

TO THE

38TH GENERAL ASSEMBLY.

MDCCCXX

JEFFERSON CITY:
TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS.
1895.

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TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS.
1896.

MR. SPEAKER: Your Committee on Printing, to which was referred the biennial report of the State Geologist to the 38th General Assembly of Missouri, recommend that 300 copies of the same be printed for the use of the members of the House and 700 copies for the use of the State Geologist for distribution.

Read and adopted February 12, 1895.

Attest: ALBERT GRIFFEN, Chief Clerk.

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LETTER OF TRANSMITTAL.

JEFFERSON CITY, January 2, 1895.

To the Thirty-eighth General Assembly of the State of Missouri:

GENTLEMEN—In accordance with section 5268 of the Revised Statutes of the State of Missouri (1889), the Board of Geology and Mines begs leave to lay before you the following report of the operations of the Bureau for the past biennial period:

The appropriation made for the Survey by the Thirty-seventh General Assembly required a considerable curtailment of work. At the first meeting of the Board, after the adjournment of the Legislature, a plan for concentrating the work along certain lines was determined upon. It was the purpose of the Board to complete work which had been in hand for several years, and for which there was an urgent demand from the people of the State and elsewhere. At a meeting held April 2, 1894, the Board deemed it necessary for the good of the work to make a change in the office of State Geologist. Mr. Arthur Winslow was removed, and Dr. Charles R. Keyes was employed in his stead. After the removal of Mr. Winslow, and before the employment of Dr. Keyes, the Board entered into a contract with Mr. Winslow by the terms of which he agreed, for a fixed consideration, to complete the report on lead and zinc, on which the survey has been engaged since its organization. Mr. Winslow has since completed the work. The selection of Dr. Keyes for continuing the work of the survey was made after a careful consideration of the credentials of numerous and well qualified scientists, and after consultation with eminent geologists from various parts of the country.

Dr. Keyes was called from the position of Assistant State Geologist of the Iowa Survey, where for the preceding two years he had practically been in charge of its work, and had earned for himself the reputation of a good organizer, an economic administrative officer and an indefatigable worker. He there, with an appropriation of only $20,000, succeeded in preparing for publication three volumes, comprising nearly 1500 pages, concerning the geology of Iowa, which have received the highest commendations of not only professional, but practical business men, enhancing greatly the best interests of the State. He is a quick, careful and accurate observer, and a rapid, voluminous and interesting writer, having published during the past dozen years eight volumes and over 100 memoirs, all representing original investigations along the line of geology. His demonstrated standing and ability and his wide familiarity with the geology of the Mississippi valley, and especially of Missouri, gained in part while serving for two years as Assistant Geologist on the Missouri Survey, commended him to the Board as the person best fitted to carry on the work in an economical manner with the production of the largest possible amount of valuable results. Since his occupancy of the office of State Geologist of Missouri, his energies have been expended mainly in the work of supervising the publication of various reports, and in completing and editing various other reports, as set forth in his statement herewith submitted. This, together with the formation of plans for the execution of future work, as more fully detailed by himself, heartily commends itself to the approval of the members of the Board, and they have every confidence that the State will receive full value for every dollar appropriated.

The following is a summary of the expenditures of the appropriation made by the last General Assembly:

	Jan 1, '93, to April 25, '94	April 25 to Dec. 31, '94	Totals.
Salaries	$8,039 22	$1,289 85	$9,329 07
Special and temporary assistance	2,461 56	641 65	3,103 21
Railway fare, wagon hire and subsistence	1,055 08	207 79	1,262 87
Printing and binding reports	415 73	3,168 09	3,583 82
Engraving maps, plates and cuts	761 16	548 28	1,309 44
Freight, express, postage	517 29	137 38	654 67
Supplies, books, etc	682 20	73 62	755 82
	13 932 24	6,066 66	19,998 90

Since the organization of the Bureau in 1889, the following publications have been made:

In 1890, three bulletins aggregating 545 pages.

In 1891, two bulletins and a preliminary report on coal, aggregating 393 pages.

In 1892, the Higginsville sheet and two volumes of reports on iron ores and on mineral waters, aggregating 722 pages.

In 1893, no publications were made.

In 1894, the Bevier and Iron Mountain sheets, the reports on lead and zinc, and paleontology, aggregating 1242 pages. The two latter have not yet been fully bound.

There are now virtually ready for publication the following, which should be issued at once:

Annual report of the State Geologist.
Six sheet reports.
Report on Granite Rocks of the Southeast.
Dictionary of Elevations.
Formations of the Coal Measures.

By the first of June next the report on clays and six sheet reports promise to be ready for publication, and before the end of the biennial period, in addition to the other reports, the important report on building stones will be completed if funds permit.

The great importance to the State of the continuance of the work of the Survey is recognized by the Board, and is shown by the constantly increasing demand for information concerning Missouri's resources. The Board therefore unanimously recommends to you the propriety of the following appropriations for the next biennial period:

For maintenance	$15,000.
For printing	$14,000.

The appropriation asked for maintenance is small, and is the minimum amount upon which the Survey should be carried on.

The amount requested for printing is required for the publication of a number of investigations begun several years ago, which the Board deem important to complete at once, and it is confidently believed that you will recognize the expediency of placing before the public as rapidly as possible the results of the Survey. The work of the Survey is now in such a condition as to justify its continuance on a moderate scale. It is the policy of the Board to operate with moderate appropriations, taking up only a few lines of inquiry at a time, and as rapidly as consistent with accuracy to complete and publish the results of the investigations. In this way we believe the State will derive the greatest benefits, and the Survey best commend itself to the hearty appreciation of the citizens of the commonwealth. In conclusion, your careful consideration is invited to the detailed report of the State Geologist herewith submitted.

WM. J. STONE,
President of the Board.

THIRD BIENNIAL REPORT

OF THE

STATE GEOLOGIST

BY

CHARLES ROLLIN KEYES.

BOARD OF MANAGERS.

His Excellency Wm. J. Stone, Governor of Missouri,
ex officio President of the Board.

Dr. J. H. Britts	Clinton
Prof. W. H. Seamon, School of Mines	Rolla
Hon. W. O. L. Jewett	Shelbina
Prof. E. M. Shepard, Drury College	Springfield

PREFATORY LETTER.

Missouri Geological Survey,
Jefferson City, Dec. 31, 1894,

To the President, Governor William J. Stone and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen—In accordance with the provisions of the law under which the Geological Survey of Missouri was organized, I have the honor to submit to you a report of the work done under my direction. In connection with this statement I have also given you a concise summary of the status of all operations carried on since the establishment of the survey, the work now in progress and the investigations yet necessary in order to finish a complete geological survey of the State.

Your obedient servant,

Charles Rollin Keyes,
State Geologist.

BIENNIAL REPORT OF STATE GEOLOGIST.

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INTRODUCTORY.

Among the states of the great Mississippi valley, Missouri ranks first in the value of mineral products. The reason of her high position lies not altogether in the fact that the respective ranks of the several states are according to the real worth of the mineral resources contained, but rather in the fact that Missouri first offered encouragement to the development of her natural wealth. With early foresight she began a systematic investigation of what nature had endowed her with. Although short-lived, the result of the inquiry did more, perhaps, than any other one factor to set before the world all her latent riches. The great material development which the State has undergone dates from this time. The people of the Missourian commonwealth can never appreciate too highly the fruit of this first attempt to carry on a systematic survey of the State's domain. How fully, incomplete as the work was, it furthered the material betterment of the State, every citizen knows. The answers given them by the state geologist to the question, How will the geological survey aid us? are as true today as they were forty years ago :

> "If properly conducted, it cannot fail to develop the mineral resources of our State, and place our mining interests on a more permanent basis, by inviting capital, and by securing systematic and profitable operations.
>
> "It will increase our mechanical and manufacturing interests, by pointing out the raw materials and the facilities for converting them into articles for domestic and foreign trade.
>
> "Agriculture will be advanced by investigating the structure and the chemical properties of the soils, as the results will enable us to determine the modes of culture necessary to sustain and even increase the productive energies.
>
> "Commerce will also receive a new impulse, from the increased products of the farm, the mine and the work-shop.
>
> "Should the survey be made with minuteness to point out the soils of each township, the facilities for settling and the great prosperity of our agricultural communities, the reports would attract thousands of those who are yearly seeking homes in this great valley. The increase of our yeoman population and tax-payers thus secured, would soon be felt in the financial and political resources of the State.

"The development of the mineral and agricultural resources will so enhance the value of land in the State as to make an aggregate increase of a vast amount."

The same sentiment is echoed in a recent editorial, which appeared in one of the leading and most progressive of newspapers; while it is further added:

"Our artesian waters will be thoroughly understood, so that anyone in the province by simple calculations may determine within a few feet how far he will have to bore to obtain good water, and how much of a flow he will secure.

"The water-powers of every stream will be definitely known, and the conversion of this energy into electricity will eventually give us light and heat for the whole region.

"New coal fields cannot fail to develop, and the limit of the present ones will be definitely made out, so that the great sums of money now annually expended uselessly in vain searches for this mineral in portions of the State where it cannot possibly occur, may be saved and turned into more productive channels.

"Our building stones will be thoroughly tested and carefully located, for without the slightest doubt, Missouri has as good building stones as can be found in this country.

"The clay industry will receive a great impetus. Instead of importing large quantities of brick and other clay products, we would be exporting greater quantities to all the neighboring districts. The aluminum clays would also receive careful attention."

OBJECT OF THE GEOLOGICAL SURVEY.

To Missourians, it is entirely unnecessary to go into details regarding the benefits to be derived from an economic geological survey. It is enough to know the favor everywhere with which the work has been received, and that the neighboring states are following the example set and are establishing similar institutions. But there are several points which cannot be too frequently emphasized.

It is one of the most universal practices for a keen business man or a prosperous merchant, when he wishes to know exactly how his affairs stand, to take an inventory of his possessions. A state, in establishing a geological survey, has also in mind an inventory of her possessions; that is, of her natural products, all those mineral substances which may be made to serve useful purposes. But a geological survey is much more than a simple inventory—a mere taking account of stock. It not only lists the various minerals, but locates them accurately, investigates their qualities, extent and accessibility, notes their particular uses and value, and suggests improvements in the methods of obtaining and treating them for commercial purposes. In order that the information may be readily and accurately interpreted, the determinations and facts are recorded and explained on suitable maps or in the descriptive notes which accompany them.

But the direct purpose and scope of the work is often misunderstood, for in the establishment of the Geological Survey it was manifestly not the intent of legislators, as many persons suppose, to replace, by State work, individual testing and investigating, but rather to encourage and supplement personal efforts, and thereby greatly lessen the chances of failure.

Through the work of a completed geological survey there may be mentioned, among the general objects to be attained for the State:

1. The provision of a suitable foundation for detailed and intelligent search for mineral wealth. One of the chief benefits resulting from this work is the limitation of different mineral-bearing areas in which prospecting may be profitably undertaken. The necessity of this course has appeared all the more urgent as the work of the Survey has progressed. It may be a matter of considerable surprise to learn that carefully made estimates show that more money has often been wasted in many counties in a single year, through ill-advised and poorly conducted efforts to discover coal and other minerals, than would annually support a systematic investigation of the entire State. Numberless abandoned diggings are met with, most of which mark fruitless efforts to obtain minerals in places where success is as utterly hopeless as could be imagined. All this useless expenditure of capital and labor might have been largely avoided, had some authoritative information concerning the geological features of the particular localities been accessible.

2. The assurance of permanency in the development of resources already known. Means are provided beforehand by which, without encountering repeated failures and inconveniences, each one may know how to turn his discoveries to best account, how to work the deposits to the best advantage, and how to prepare the product in the most suitable manner for market. The properties of the different substances and the uses to which they may be put having been determined in a practical way, the further advancement of the dependent industries is greatly simplified. On the completion of the work on any subject, all information possible is brought together, so that when a person engages in any mining enterprise or business connected with the natural resources of the region, he can hardly fail to find in the particular report something which will greatly assist him in his efforts, and prevent a useless waste of time and money.

3. The establishment of an official guaranty respecting the natural wealth of the State. Information given by disinterested persons concerning the State's possessions is always regarded as more trustworthy than when imparted by private individuals. Citizens at home, as well

as abroad, have confidence in making investments, and feel that they are not entering into mere speculative fields.

4. The formation, on a scientific basis, of a standard by which the geological features of the region may be compared with those of other districts. There is a wide demand for something of this kind for purposes of instruction in schools and colleges. Text-books commonly used consider only the principles of science; the reports of the Survey supplement this outline by giving detailed information of local application.

5. An advancement of agricultural interests. This is more fully considered elsewhere under the subject of soils.

PREVIOUS WORK.

Owen's geological reconnoissance of the upper Mississippi valley in the later forties, under the auspices of the Federal government, gave to the world the first scientific account of the mineral wealth of the region. A year after the appearance of the report, Missouri instituted a special investigation of her natural resources. This geological survey of the domain was begun under favorable conditions, and the grand results of the first years of its existence in pointing out to the civilized nations of the globe the great mineral wealth of the State are known to all. But before the work had been fairly begun, unforeseen circumstances of national import arose, causing a cessation of operations for more than a decade. Reorganized in 1870, work was commenced anew, but owing to the calls one after another of the directing spirits to other fields of action, investigations were again given up after a few years. Nearly fifteen years elapsed before the geological survey of the State was again renewed in the present organization. Although up to the time of the last revival of official geological work in the State the existence of the survey had been fitful, it was not without invaluable results; how much more valuable might they have been had it been conducted under favorable conditions and without embarrassment can only be conjectured. Yet, owing to so interrupted a career, it is safe to say that not less than three-fourths of the information obtained has been practically lost to the public. Dear experience, then, not only in this State but in other states as well, has taught that a temporary survey is money largely expended in vain; that if it cannot be carried to completion, the investigation should never have been commenced; that being established and so well begun, it should be liberally encouraged to completion, that its results may endure for all time to the advancement of the State.

ORGANIZATION OF THE GEOLOGICAL SURVEY OF MISSOURI.

Six years ago the people of Missouri, through their representatives in the General Assembly, authorized the completion of the geological survey of the State. It is doubtful whether at any other period of Missouri's history has she felt more the need of a thorough economic investigation of her native wealth. The survey contemplated was not an investigation such as was vaguely conceived by many, but one broad in its scope and far-reaching in its workings—one whose primary aim was to bring before the public the State's natural products, to encourage her material development, and to invite the investment of outside capital. Indeed, it had long been a matter of general regret that a commonwealth so happily supplied with boundless natural riches should have so little official information concerning them, to which either her citizens or the public at large could turn.

The law is certainly liberal in its application, comprehensive in its requirements, practical in its bearings. Not the least valuable of its measures is the provision for the diffusion of useful knowledge among the citizens of the State. The demand for authoritative information of this kind has long been so urgent, that it is a matter of much surprise that steps in the proper direction were not taken years ago. To be sure, such a movement has been twice started and twice rendered inactive, first in the fifties and again nearly a quarter of a century ago. Being only temporary, they were largely preliminary, and the results were necessarily very incomplete. Moreover, during the past two decades much information concerning the mineral wealth of Missouri has accumulated, and when brought together in a connected way with the results of other investigations it will be of the greatest value. In the same period, geology itself has made gigantic strides, not only scientifically, but economically.

The great interest now shown in the examination of the natural resources of Missouri, is not wholly confined to the people of the State. There are probably as many persons living without the borders of Missouri as there are within them, who are keeping themselves informed as to what is being done by the Survey. Indeed, the work has met with as universal favor and appreciation abroad as at home. As was well stated not long ago in one of the leading newspapers, Missourians are, as a rule, too busily occupied with their own affairs to go much out of their way to get information in regard to that which does not connect itself directly with the advancement of their own material terests. The benefits of the Survey appear to some people to be only indirect; hence, there is often by these persons a lack of proper appreciation of the aims and ends of the work. As the real facts become known, and the citizens become more and more acquainted with the doings of the Survey, it is extremely rare that a warm interest is not manifested. The solicitude for the carrying out and completion of the investigations begun is not shown in Missouri alone. As the published reports are made accessible, they are reviewed and talked about, more or less, in almost every country of the globe.

Along with the report on the progress of the Missouri Geological Survey, it has been thought desirable to present in some detail the general scheme of operation. As will be readily seen, the entire plan of the Survey is practical in its aim. While thoroughly economic in all its aspects, the work is so arranged that it may be carried on in a manner perfectly systematic and scientific. At all times, the investigations are conducted in a way which it is thought will best serve the interests involved.

GENERAL PLAN.

Ever since its first organization, the Missouri Geological Survey has come to direct its energies more and more to the investigation of the mineral wealth of the State from the standpoint of the utilitarian. Recently strong efforts have been made to concentrate the work still farther.

From the beginning, two classes of work have been recognized. One is rather general in its character, the other more specific. The first is denominated subject work; the second areal work. With the first it is the practice to take up each particular topic, as coal, clay, iron, lead, zinc, or soil, and to consider the deposits as a whole for the entire state. In contradistinction, areal work has for its object the treatment of all useful mineral deposits of limited districts, as a county or other convenient area, special attention being given to the local details and the accurate mapping of the different geological formations. In its main features this dual arrangement of the work has been the policy of the Survey from the start, though modifications in many details have taken place from time to time, as the changes in conditions necessitated, and as the enlargement of the scope of the work demanded. A third class of facts might be properly grouped under the head of statistics; while the fourth line of work pertains to the publication of all results.

SUBJECT WORK.

Subject work is of first importance in conducting geological investigations, for the reason that it satisfies a wide demand for information concerning the existence, mode of occurrence and properties of the various mineral substances. Deposits are not limited by modern political boundaries. Each kind of mineral, clay, or other natural product dug from the earth, belongs to some particular geological formation: that is, it is found at some horizon or level more plentifully than at others. Thus, one formation is abundantly supplied with coal, another with the ores of zinc and lead, a third with materials for the manufacture of cements, and others with still different substances of economic value. Each is found in a particular geological zone, and rarely or very sparingly elsewhere. Only within certain districts would search for a given substance be successful; outside of these areas no amount of prospecting would ever disclose the material sought.

In obtaining information concerning each particular mineral substance, the entire subject must be carefully considered. At the outset a clear understanding of the geological structure of the rocks containing it is of prime importance. The localities where each occurs require description; the arrangement, relations and extent of the deposits must be defined; the origin and properties discussed; the accessibility and value determined; the uses of the substances, the nature and status, both present and probable future, of the industries connected fully considered. A complete report on each special subject is therefore comprehensive in character and concise in statement. This work cannot be weighted with the details of only local interest, as this would extend the account far beyond the space that could be allotted to it. Information of an entirely local character must be recorded largely on maps or described in accounts of areas.

In the beginning, then, subject work is more important or at least is more prominent than areal work in dealing with all of the useful mineral substances found. It necessarily includes two classes: (1) the principal topics, which are the larger subjects, each requiring a very considerable period of time to finish, and (2) the subordinate subjects, which comprise numerous minor points. The former, of course, are taken up first. While they are being investigated facts are continually accumulating in regard to the collateral subjects which, with a little special attention later, will ultimately be brought together, forming valuable additions to what is already known concerning the resources of the state.

The advantages of having the work done according to topics are numerous:

1. Since particular mineral substances, as already stated, are rarely confined to single counties, but are usually distributed over several

and sometimes many such districts, it is necessary to investigate each kind of deposit in its entirety. It may then be told with certainty how, and to what extent, the several locations will be benefited by the development of such minerals.

2. The general discussion of the properties, uses and magnitude of each deposit may be taken up, and the results published long before all of the work in the counties containing the particular substance can be furnished.

3. In order that lasting results may be obtained more or less work of a general character is always necessary for the intelligible interpretation of the phenomena observed in any one county and to connect them with those seen in neighboring districts.

4. The investigations may be made by experts or specialists in the different lines. The results accomplished are therefore much more satisfactory, more accurate and far more valuable than if obtained in any other way. Furthermore, much less time is required and the cost is consequently very much less.

5. Since most people are engaged in one industry only, the information in which they are most interested is brought together. The miner wishes to be informed about coal, the quarryman, architect or engineer seeks good building-stones; the brick maker desires something regarding the properties and adaptabilities of the different clays; each wants to know in regard to his special field and cares little or nothing about the others.

AREAL WORK.

In area work the economic resources of particular and limited districts receive consideration. Detailed information of a local character is considered; the present and possible future developments of the mineral wealth are set forth. Its direct purpose, then, is to satisfy constant and ever increasing demands for reliable information in regard to given localities. The desire to know about the mineral products of each particular neighborhood is so general that full details are required concerning every substance which is, or is likely to be, of value to the land-owner or occupant of the district. Probably one-half of the people of the State seek this local information.

Local information in districts is imparted in three ways: first, by descriptions and sections; second, by illustrations, and third, by maps. Probably three-fourths of the geological facts are recorded cartographically. In consequence, therefore, a modern geological map is a graphic summary of a vast amount of useful information. In addition to an accurate representation of the ordinary geographical features, as in the best atlases, a properly constructed geological map records much more. On it are indicated, within a few feet, the elevations above the sea-level of every point within the borders of the area; the drainage basins and the water powers; the distribution and limits of the different geological formations, the various kind of ores, building-stones, clays and all minerals of economic value contained in the several beds, and the best places for obtaining all these substances. The map also forms a reliable soil index which, with some additional explanation serves also as a guide to the distribution of the forests and plants generally.

But all the districts of the State cannot be treated alike in the mapping. Some places require far more work than others, either on account of the great importance of the mineral deposits or the natural difficulties caused by the ruggedness of the country. Other regions, as those which contain the principal iron ores, the most valuable lead and zinc deposits, or particular beds, require in the beginning accurate relief maps. Places where the immediate mineral wealth is not so great, do not need elaborate topographical maps. At the present time it is not advisable, nor even if it were desirable, would the resources of the Survey permit it without a very considerable enlargement of its powers. The work must go on as rapidly as is consistent with good and accurate results. In order of their importance must the various districts be mapped, and in proportion to their mineral wealth must the details be recorded.

The preparation of a full set of maps of this kind is not the result of a few days' effort, but of the labor of several years. As a part of the investigation into the economic resources, there is in contemplation a series of maps which shall embrace for every section of the State all of the information above mentioned. Some of them will be somewhat general in their character and will accompany the different special reports. Others will be more detailed in plan and will cover given counties or such other areas as may be thought desirable.

Among some of the last named the folio plates accompanying the sheet reports are examples. In the construction of maps showing the distribution and occurrence of mineral substances it is of prime importance that the surface relief should be depicted in a readily intelligible manner. One which represents most closely a perfect miniature of the surface of the region is far superior to any ordinary atlas. It is invaluable not alone to the trained geologist, but is about the only practical way by which the average citizen is able to comprehend at a glance the explanations. In proportion as the exactness with which the diminutive representation approaches the actual surface, in the same proportion does the usefulness of the work increase. The modern methods of making maps are so far advanced over those of a quarter of a century ago that there is now no excuse for any community to be without the best.

Briefly, then, a properly constructed geographical map of a district, not only locates accurately the various mineral deposits, but also represents the prominent landscape features by which the locations may be more readily recognized. A relief map also serves other purposes. Upon it may be based models of the more important districts which are to be taken as characteristic of much larger areas, and which are to represent in a graphic manner the structure, arrangement and relations of deposits. Eventually a relief model of the entire state may be constructed on a suitable scale. Besides for the purposes mentioned, it would afford one of the most instructive objects for presenting to the pupils of schools the geographical features of their state. With the wide introduction of the new methods of teaching geography the value of such aids cannot be overestimated.

STATISTICS.

Though not strictly geological in its character, the collection of statistical matter concerning the work and output of the various industries dependent upon the natural resources of the states comes properly within the scope of the geological survey. By means of this information accurate comparisons of the yearly progress made may be instituted. The figures are obtained in two ways—partly through printed circulars and accompanying blanks sent to the respective trades, and partly by personal visits of different members of the geological corps, in course of their investigations. All information is considered as strictly confidential; and the tables of comparison are arranged by counties in such a way as not to disclose the details of any individual business. The unusually favorable opportunities offered by the Survey's facilities makes this class of figures of particular value, especially in the case of those industries about which little is now done in this direction.

PUBLICATION.

No feature in the investigation of the natural resources of the state is of greater importance than the placing of practical information in regard to the various deposits before the people as rapidly as possible, and at the same time in a measurably complete form. Therefore, in making public the results of the geological survey of the state, the common practice of transcribing field notes and of making incoherent preliminary reports on different subjects has been discarded.

The general plan of field work is, of course, arranged so as to accord with the ultimate presentation of the results in printed form. Hence, two general divisions are recognized in publication, as in the field work, though their distinctions may not be so obvious at first glance.

The adoption of a single series of publications, uniform in size, in general style and in binding, it is thought, will do away with much of the inconvenience and many of the objections arising from the various ideas of different individuals as to what is the most appropriate manner of getting out work of this kind, or from an adaptation to the particular facilities possessed by the various printers. As nearly as possible each volume will contain in the neighborhood of 400 pages, besides the necessary illustrations and accompanying maps. There will be, however, one exception—the final state atlas. Although numbered consecutively, the separate volumes are in no way dependent upon any which have gone before or any which may follow. Each may therefore be regarded as complete in itself. This plan enables one volume to be devoted to one topic and another to another. It permits the placing of results before the public as rapidly as the investigations are completed, without long and vexatious delays. A particular deposit extending into a number of districts may thus be studied thoroughly and a report made without waiting for the entire work in the several counties to be finished. Similarly, different counties or areas may be reported upon before any special deposit is examined over all the state. In some cases the work requires a very much longer time to complete than in others; and it is often very desirable, especially with the larger subjects, that some information be made accessible before the appearance of the final report. When the work of any particular topic has reached a more or less advanced stage of completion some special phase of the subject may be briefly discussed and emphasized in advance, but the article is always made complete in itself, depending neither upon anything which has been nor which is to be published.

The publication of results is also brought about in two other ways: (1) through the newspapers and (2) through scientific and trade periodicals. To the newspapers are sent accounts of new discoveries and carefully prepared articles of general interest on particular deposits of certain districts. Information of a preliminary character is thus also given to the public months before the entire work is completed and published. At the same time popular interest is enlivened and a stimulus given to local investigations. Topics of unusual geological importance are frequently discussed in papers which appear in the various scientific journals.

PROGRESS OF THE WORK.

In the general scheme of investigation which is conducted by the geological survey, and as the operations go on there come to be recognized four general classes of work: (1) work completed; (2) work in progress; (3) work taken up incidentally; and (4) work yet to be commenced.

Work Completed.

Under the first of these heads is embraced all the lines of work which have been investigated thoroughly and reported upon. Of course, it is understood that this does not mean that no more observations will be made in these directions, but rather that until all the deposits are reported upon, they will have a subordinate place in the general scheme. On all topics new facts are being constantly brought to light and new phases of the questions are arising. All information of this kind is preserved, and eventually it is brought together in a supplementory report before the completion of the survey.

As to the work in progress it may be said that reference is made directly to the principal lines of investigation which are being actively carried on. Many subordinate topics are dealt with at the same time which will ultimately become chief subjects as the other lines are finished.

The third group of observations are complimentary to the second. Facts are constantly accumulating concerning areas and deposits which cannot possibly be taken up as principal lines of investigation at once. Yet, by the time these lines are taken up for completion much valuable information will have been accumulated, and the outlines arranged for a speedy finish.

Concerning the last class it is, perhaps, hardly necessary to state that it is a physical impossibility with the present resources of the survey, to consider all subjects in the beginning. Some must wait until others are disposed of. With the means at command at present, the different topics must be taken up and investigated largely in the order of their importance, or because unusually favorable facilities are presented for an early consideration. That some important subjects have been seemingly neglected is not for reason of any underestimation of their true value and place.

IRON ORES.

One of the chief results of the first systematic work done on the geological features of Missouri was the setting before the world the great value of the iron deposits of the state. Considerable attention was subsequently paid to the same subject at different times, but the recent decline in the iron industry of the state has again awakened special interest in this topic, and has hastened a revival of the inquiry which was abandoned more than twenty years ago.

Briefly stated, the aim of the work was to establish districts in which iron ores are most abundant, to ascertain the exact character of the deposits, in order that prospecting may be done in the most intelligible way, and to determine whether or not the conditions are favorable to the establishment of local smelting works. The results have been gratifying. In carrying out the work, the greatest amount of time was given to points practically untouched, though controlled by the promise of iron ore in a given district, and the remaining time was distributed as seemed best to serve the objects of a general report upon the iron ore of the whole state. In a former account, considerable attention was paid to the limonites on the Belmont branch of the St. Louis, Iron Mountain & Southern railroad, and on the Middle Osage river. The ore bodies there pointed out are yet hardly touched, especially the Osage deposits, and attention has therefore been called to these localities as possible ore fields. The whole tier of counties along and immediately above the Arkansas border, from and including Stoddard county to Taney, was hardly touched. There are ten counties and only six localities reported. Recent work shows this field to be at least as productive as any in the state, and, consequently, much time has been devoted to it. Even the most conscientious effort to locate every outcrop of iron ore would in the end fail in the present state of development of the country. Enough work has been done to prove that limonite ore exists in sufficient quantities to warrant the erection of local furnaces for its smelting, and that other conditions are favorable for such an enterprise. This fact has been enlarged upon in the report.

The location of ore deposits means, however, more than the mere fixing of these outcrops alone. One outcrop points certainly to others, neither now located nor reported, and the particular aim of the work done has been to point the direction in which others may be confidently looked for.

The outcome of the investigation has been the examination of the iron ore deposits in forty-three counties. It has included a determination of the general extent of iron ores in the various districts, an inquiry into their origin, an outlining of the general conditions of their distribution, a consideration of the qualities of the various ores, for which purpose a number of samples were collected, of which chemical analyses were made. In addition to fully discussing these topics, the report, which embraces nearly 400 pages, describes all the more important occurrences, and conveys recommendations regarding the best means for their development.

In further carrying on the work on the iron ores of the state, the efforts of the survey will consist largely of systematic and detailed mapping in the iron ore regions, so that the distribution of the ore bodies, as well as the other surrounding conditions, may be shown in greater detail.

MINERAL WATERS.

As stated in the report on this subject, the investigation of the mineral waters of the state was one of the first subjects to engage the attention of the present survey. Missouri, although not in possession of many handsomely improved resorts whose waters are of such wide reputation as to attract many visitors from abroad, has yet a great number of mineral springs, many of them of undoubted medical value, which are patronized by citizens of the state. The majority of people are unable to avail themselves of the cures of the well-known but distant resorts, and hence have recourse to what is provided at home The investigation and the preparation of this report were hence undertaken principally for the following reasons: (1) to determine the composition and character of the waters and their values as compared with other waters which had acknowledged medicinal virtues; (2) to furnish an exact and full statement of the results reached, particularly for use of physicians; (3) to supply certain suggestions for the guidance of the citizens of the state in the use of these waters; (4) to make the fact of the existence of these waters authoritatively and widely known with the object of interesting others in developments and improvements at the different localities.

The results of the inquiry have been to give a full explanation of the origin, composition and therapeutics of the various mineral waters; to discuss the different kinds found within the limits of the state, and to describe fully all the springs and wells. The report is embraced in one volume of 280 pages, with 45 illustrations.

FOSSILS.

The review of the fossils of Missouri is a radical departure from the usual reports on the subject of Paleontology, in that an attempt has been made to make it as strictly economic in its bearing as possible. Instead of giving new names to an endless number of forms, accompanied by long technical descriptions, it has been the aim rather to avoid them so far as possible. The economic value of fossils is commonly overlooked. Ordinarily these remains of ancient life are regarded merely as curious; to the specialist the interest in the old organisms is wholly scientific; but by him who is fairly well acquainted with their character, and who is engaged in practical geological work, the rocks are read as a printed page. One of the best established facts of modern geological science is that there is an intimate relation between all mineral deposits and the surrounding rocks; hence the age of particular beds becomes an important factor in the early attempts to develop new mineral districts. These inferences rest upon one of the cardinal principles of geology, that the geological sequence of strata is determined most readily by the remains of life contained. Thus, in reality fossils are labels on the rocks, telling one at a glance the age of the beds being worked and providing the most reliable guides that could possibly be secured in directing the miner and prospector to the layers most likely to contain the mineral sought.

The widespread desire which has existed for many years among certain classes of citizens who are interested directly in advancing the mineral development of the state has created a strong demand for accurate accounts of the organic remains found in the rocks of the region. This demand is becoming more and more urgent in the light of the fact that fossils have such a distinct economic importance in the determination of the age of useful mineral deposits, and hence serve as the most trustworthy guides known in the further development of the natural wealth of a region. In the attempt to satisfy properly the calls arising in connection with the work of this character it has been the aim to present in a comprehensive report as briefly as possible, (1) an index to the fossils of the state, through means of which forms now known to occur within the limits of the region under consideration may be reconized readily without recourse to great libraries; (2) a list of the works pertaining to Missouri fossils, in which is brought together all that has been written on the subject and which is now widely scattered and practically inaccessible; (3) a concise summary of all that has been done up to the present time in this branch of science so far as it pertains to the state; and (4) a guide to a more comprehensive study involving the solution of problems now more or less obscure concerning the arrangement and relations of the various strata. In short, it is a handbook of the fossils of the state, adapted to the use of teacher, student and layman alike.

The general plan of treatment of the different species enumerated has been to give under each a more or less complete bibliography, by reference to which additional information or good illustrations of the forms not here figured may be found. In the diagnoses it has been the aim to give a rather full description of some leading representative of each genus, accompanied by a suitable figure, and to make the sketches of the other members of the group brief and in a great measure comparative. By this way of dealing with the subject it is thought that the characterizations of all the species will be sufficiently ample for intelligent comprehension, and for the particular uses to which the work will be put. At the same time the bulk of the report will be reduced very greatly—to one-fourth, at least, of what it would otherwise have to be. The horizon and some of the leading localities of each species are also given. The matter of localization has had to be rather general, allusion being made to the nearest postoffice usually, or, in a few instances, as when the fossil is common and the distribution wide, merely to the county. As a further help there has been appended a stratigraphical catalogue which is intended for ready reference, and a synonimic indexical list of all the names applied to Missouri species. With the many natural difficulties to be taken into consideration, it is easily understood that from a geological or biological standpoint, any stratigraphic tabulation of the fossils of the State must necessarily be quite incomplete for years to come and must long lack uniformity in the number and kind of organisms assigned to each horizon. Nevertheless, in the present condition of knowledge there is peculiar economic importance in a special arrangement of the forms known at the present time to occur within the limits of Missouri, or on her borders, according to the strata in which they are found. With general geographical distribution known by reference to the colored geological map, the fossils which may be expected to be found in any locality in the State, may be quickly referred to without the labor of going through the whole report to pick them out. The fossils forming as they do, labels to the deposits of commercial value, put a ready and inexpensive means in the hands of even the most inexperienced for determining what minerals of economic worth are to be sought for in the particular neighborhood, and what are not to be expected.

The report is in two parts, containing altogether over six hundred pages and fifty-six plates, besides a revised geological map of the State.

LEAD AND ZINC.

Lead and zinc form Missouri's most prominent mineral products. The real importance of these metals is further comprehended when it is known that as a producer of the first named ore the state ranks second among the states of the Union, and of the second metal first, supplying more than two-fifths of the entire amount of mineral in the United States.

The rapid growth of the lead and zinc industry of recent years made the subject one of the first demanding the attention of the survey. The magnitude of the work with its constantly increasing development can only be appreciated by one who has gone carefully over the ground. The investigation was begun, first in connection with the United States Geological Survey and later independently. Although in getting the results into permanent form for presentation, there have occurred some delays, as necessarily there must always in work of so extensive a character, the added value to the report will amply compensate for all seeming procrastination.

The report has been divided into three parts. The first portion contains an historical sketch of the metals, and a summary of what is known of them in all countries of the globe. Particular attention is given to the lead and zinc producing districts of North America with which the Missouri product is brought into competition. A chapter is also devoted to the metallurgy of the metals, and the various processes are described with sufficient minuteness for all practical purposes. Concise tables of the production in the United States are also given in this connection, together with the prices.

The second section outlines the history of mining in Missouri, and the general geology of the southern half of the State. The development of the mining in the State is traced from the time of the earliest explorations. The physical characters of the lead and zinc regions are described at length. The geological formations containing the metals under consideration are referred to in a general way, and considerable detail entered into in the case of the most important localities. The lithological differences are compared and some of the salient structural features pointed out. Under ore deposits is a full consideration of the distribution, the form, structure and composition of the ore bodies, their manner of formation and the origin of metalliferous veins. Concerning the latter topic, the various theories are set forth and their application to Missouri deposits clearly given. Smelting and manufacturing received the attention they demand, and full statistics are given regarding the production of the two metals in Missouri, the prices received from year to year, and the total output of the various counties.

The third part is an account of the Missouri mines, with a systematic and detailed description of the important developments and occurrences of lead and zinc. Three districts are recognized: the southeastern, the central and the southwestern. Here is incorporated all the detailed information concerning the various camps. Many of these are mapped and the workings of typical individual mines plotted.

This is the portion of the work which will appeal most directly to the people actually engaged in working in the diggings.

LOCAL GEOLOGY.

In the preparation of reports upon particular localities it has been found advantageous in the case of some of the most important mining districts to take as the unit a rectangular area measuring 15 minutes of latitude and longitude. This, on a scale of 1-62500, or one mile to an inch, gives a map about 13⅝ by 17⅜ inches. The unit is called a sheet, and the reports on the the areas which are named after a leading town within its borders, sheet reports. Three of these sheet reports have been completed, viz.: Higginsville, Bevier and Iron Mountain. A dozen similar ones are nearly completed.

The Higginsville sheet includes part of Lafayette county and a small portion of Ray, and embraces an area of nearly 232 square miles. The report accompanying the map describes in great detail the geological features and mineral resources. It forms a folio of 18 pages equivalent to about 100 pages of the ordinary octavo.

The Bevier sheet report in a similar way is based upon a detailed examination which has been carried on in portions of Macon, Randolph and Chariton counties. This account is embraced in about 85 pages, with suitable illustrations.

The Iron Mountain sheet covers parts of Iron, St. Francois and Madison counties, and represents the results of work completed in a portion of southeastern Missouri. There are 95 pages in the report accompanying the map.

Work in Progress.

The investigations concerning the natural resources of the state run along parallel lines, termed subject and areal work. While covering the same ground in part, they do not necessarily occasion duplication in either field work or publication. Of these two divisions the former, from its nature, must in the beginning receive greater attention. The very nature of the case making it impossible to take up all subjects in the beginning renders it necessary to give greater prominence to some lines of work and to finish them up before branching out in new directions. As the work is completed in the various fields and the reports are made the efforts are directed to other branches, only incidental notes being continued on those subjects which have been reported upon. Attention has already been called to some of the work which may be regarded as completed.

Concerning the work now being actively carried on, special mention should be made. Much of it is well along toward completion, and must soon be regarded as work finished.

INVESTIGATION OF CLAYS.

The work on the clays of the state is now practically completed, and the report will be ready shortly to go to the printer. The investigation has a peculiar value, and the thoroughness with which it has been conducted lends special interest. The practical experimental work on clays has never before been attempted by any state in the Union, and nowhere in the Mississippi valley has this class of material received so careful a consideration. In the testing of the clays, not only the chemical, but also the physical properties are determined. Through the latter especially the various comparisons may be more thoroughly appreciated, and the exact character of the different deposits more readily understood. The following outlines the method, taking for example a sample of typical fire clay.

A preliminary examination shows:

Color varying from light ash to drab.

Texture nearly uniform, fine grained, compact.

Taste "lean," gritty.

Slacks slowly into irregular granules, with little uniformity of size.

Accessories: pyrite not perceptible; sand as grains from one-tenth to one-thirtieth of an inch in size, freely disseminated.

A physical examination shows:

Specific gravity, 1,950.

Plasticity, as determined by working a clay paste, is eminent; as determined by the tensile strength of air dried briquettes it has a maximum of 172, the average of ten samples being 155 pounds per square inch.

Water required to make a plastic, easily worked paste is 15.4 per cent.

Air shrinkage, in drying bricklets ranging from four inches by one-fourth inch to eight inches by four inches averaged 5.6 per cent in ten samples. It can be dried rapidly in a warm air bath at 125 to 200 F. without breaking.

Fire shrinkage, in burning air dried samples at a vitrifying heat averaged 2.3 per cent in three samples; requires care and slow heat to avoid cracking.

Total shrinkage, or the sum of the fire and the air contraction, averages 7.9 per cent, which is remarkably low.

Fusion takes place at about 2,400 F., or a white heat; incipient vitrification takes place at 2,100 F., or at a bright cherry-red heat.

Color of burned clay is light-gray.

Conclusions: This fire clay is a fairly good refractory material used for temperatures as high as 2,300 F., or a very bright cherry heat. It admits of rapid air drying without cracking, and does not fissure readily in firing. The total shrinkage being very low adds greatly to its value in any practicable application of the clay. Being highly plastic, it moulds admirably. The burnt ware is quite strong. The clay, when washed, may be used successfully by potters. It is even possible hat a white ware may be produced if the clay is properly washed and treated.

Among the subjects exhaustively discussed in this report are:

1. The origin and composition of the clays of Missouri.

2. The methods of sampling and analysis.

3. The physical and chemical properties of the various clays.

4. The microscopical examination of clays and its value in the determination of the value of a deposit.

5. The uses to which the various kinds of clay are and may be put, and a consideration of the best varieties adapted to each specific purpose.

6. The general geology of the state with special reference to clay deposits, their distribution and availability.

7. The brick and drain tile clays, the localities yielding the best qualities and the methods followed in rendering the poorer grades workable. There will also be embraced a special consideration of the clays used in making paving brick and sewer-pipe. The recent extensive use of brick as a paving material and its superiority over many other substances has rendered the subject of brick for this purpose one of very great importance and one to which sufficient attention has not yet been paid. Paving streets with hard bricks is fast becoming popular in the larger towns and cities. Tests are continually being made which go to prove that the durability of a street paved with good vitrified brick compares more than favorably with that of streets paved with other material.

8. Fire clays and other deposits for the manufacture of refractory products. There will be given in this connection extensive comparisons of the raw materials from the different localities in the state, and reference to noted places beyond its limits. Deposits of this material have been found in large quantities and of very superior quality.

9. Pottery clays, their properties, distribution and location; also the materials used for glazing and in mixtures.

10. China clays and kaolin, of which large quantities have recently been brought to light in the southeastern part of the state especially.

11. The principal industries based upon clay, and descriptions of the works and clay pits.

12. Preparation of clay for manufacture into the different products, and the methods used.

13. Recommendations for better methods of manipulation. The importance of raising the standard of excellence of clay goods can not be overestimated. It not only aids directly the manufacturer of the products, but indirectly greatly benefits every citizen by providing him with a superior quality of material at no higher a price than he would otherwise give for the inferior article.

14. Complete statistics in regard to the production of the various kinds of clay goods.

Besides, the report is accompanied by a full bibliography of the writings on clays and a complete glossary of terms used. When printed the volume will contain in the neighborhood of 700 pages, divided into 21 chapters and 6 appendices. It will be accompanied by several large maps and over 40 full-paged engravings, besides numerous cuts.

Altogether, the report on clays will form one of the most valuable contributions to economic geology ever published, not only for Missouri, but for the entire United States. It completes one of the most important lines of work yet undertaken by the survey.

STUDY OF THE CRYSTALLINE ROCKS.

The granites and porphyries of Southeastern Missouri are of unusual interest and great commercial value, for the reason that they are the only crystalline rocks occurring in the Mississippi valley between Central Arkansas and Lake Superior, and between the Appalachians and the Rocky mountains. The development of these areas is therefore of special importance on account of the wide extent of territory they are capable of supplying with a high grade of building and ornamental stone.

The investigation has consisted in mapping all the areas and making a careful examination of the different occurrences. The microscopical characters have received particular consideration, and mineralogical composition determined with great detail. By this means comparisons have been made with similar rocks from other localities which are now used largely for building materials, and with which the Missouri stone must come into competition when placed on the market. This work is practically completed. The determination of a few odd points will enable the account to be printed shortly. The report, in addition to discussing the topics already mentioned, will also take up the general geology of the crystalline rocks and the relations of the various masses to one another. Since the rocks considered in this connection are the only ones found within the limits of the state which are truly eruptive or igneous in origin, the subject deserves more than passing notice, both from a scientific and a popular standpoint. The fact that one part of the state was once the seat of energetic volcanic action creates a widespread interest in these rocks.

WORK ON THE COAL DEPOSITS.

The investigation of the coal deposits of the state was one of the first subjects taken up after the organization of the survey. Notwithstanding the fact that this material ranked among the most important of the mineral resources of Missouri, and the state stands ninth among the states of the Union in coal production, less was known concerning its structure and distribution than perhaps any other deposit of economic value.

The investigation was begun by selecting the localities where mining was in progress, it being the object to obtain all data possible from districts already well-known. "As an outcome of this preliminary work there have been printed, and in large part distributed, a preliminary report upon the coal deposits of the state. This report contains over 200 octavo pages. As is implied by its title, however, and is distinctly expressed in the preface, it is essentially a preliminary report. It is in large part a presentation of only the bare facts of the occurrences of the coal, the facts of most direct economic importance, and these are presented in a popular way. The justification for the presentation of such preliminary report lies in the urgent demand for information concerning the subject; but, though this report is calculated to satisfy this demand to a great extent, it should by no means be taken as a measure of all that can be presented, and all that will be attained through the work in the coal regions."

The most important part of the investigation yet remains to be completed. Practically nothing concerning the correlation and stratigraphy of the seams has been published as yet that applies directly to the state. Since the appearance of the preliminary report, much valuable information has accumulated, and during the past few months the subject has been taken up with renewed vigor. At the outset it was found that in order to make satisfactory progress it was necessary to carry on the work in a perfectly systematic manner. Localities must be studied first which are likely to furnish most readily a key to the structure, character and disposition of the coal beds over large areas. The leading geological features of these districts must be carefully made out, and the examination extended into neighboring regions. In this way the extent of territory covered and the amount of practical information secured is far greater than can possibly be obtained in any other way.

The area of the Coal Measures of Missouri includes nearly 25,000 square miles; besides, there are numerous Carboniferous outliers, or isolated areas, along and beyond the borders of the productive measures, which make up many additional square miles. The investigation of the coal deposits of the state is thus seen to be a work of no small magnitude. Detailed attention to the coal industry in all its phases involves labor which cannot be completed in a few months; it requires much more time to make satisfactory observations, to accumulate all facts and carry on proper tests.

In the final report on coal there are to be included:

1. A general sketch of the coal deposits and the geology of the region.

2. A detailed account of the geological features of the coal district. This embraces a full description of the different kinds of beds and their associations, the minute structure of the coal-bearing strata, the exact relations of the different seams, the distance from the surface that it is necessary to go in order to reach them, the pointing out of

notable and easily recognized strata which may serve as guides in searching for particular veins, and all kindred information of practical import.

3. A description of the uses and properties of Missouri coals, with tables of chemical analyses of all the principal varieties from the different counties, the adaptabilities of the various kinds for steam, domestic and metallurgical purposes and for gas-making. In this connection will be considered all information tending toward a greater development of the coal industry, including the utilization of coal-dust, slack and such lignites as may occur.

4. A discussion of practical mining in the state, the methods employed and improvements which may be made, the kinds of machinery used and its advantages, the best plans and the most suitable machinery for prospecting.

EXAMINATION OF BUILDING STONES.

In variety and quantity of good stone suitable for building and all constructive purposes, no state in the Mississippi valley is surpassed by Missouri. Yet no systematic investigation of the building materials of the state has ever been accomplished. That Missouri has excellent grades of quarry stones is manifest from the demands made for certain qualities. That the state should have many other equally good building stones is not unreasonable to expect. Nevertheless, the state continues to go beyond its boundaries for many of the better grades of rock for building. Of the vast sum of money which is expended every year for stone used in construction of all kinds, a large proportion goes to other states. Hence, it is greatly to be deplored that a more exact knowledge of the state's building stone was not acquired years ago. Recognizing this deficiency, an investigation of the building materials of the state was begun with the first organization of the geological survey. The subject soon proved to be much larger than was anticipated and had to be divided up, different portions being taken up by different persons. Some of the topics have already been reported upon, while others have received but little systematic attention as yet.

The work of investigating the building stones, though early commenced, was interrupted and greatly delayed from time to time on account of circumstances entirely beyond the control of those engaged in the undertaking.

The importance of the inquiry can hardly be overestimated. It is a fitting subject to be taken up by the state, and benefits all citizens alike. Architects and engineers commonly have neither the apparatus nor the inclination to make extensive tests in regard to local building materials. Consequently, they employ stone which already has its reputation established. Thus, the lack of authoritative information in regard to local resources causes the rocks of the state to be discarded, and building stones to be transported half way across the continent, and often placed upon ledges of rock in every way their equal, or even their superior. The quarrying industry at home does not receive the support it should, while foreign markets are entered and purchases made.

Among some of the chief factors which determine the value of building stone are accessibility, durability, strength, structure and reputation. No matter how excellent a stone may be, it is of course valueless for constructional purposes if it does not have good transportation facilities. Durability is a phase of the subject which cannot be determined readily from hand specimens, and is usually brought out through experience. Stones, which ordinarily withstand the influences of atmospheric agencies, readily waste away when exposed to conditions quite different from those of their native places, and the acid-laden air of great cities is especially deleterious to rock. The resistance to weathering is ascertained best in the field by careful examination of the native ledges. These observations may be supplemented by tests in the laboratory. Strength, however, is usually the only factor tested in determining whether or not a given stone shall be used.

The work is sufficiently far along to outline full the scope of the investigation. In making the observations, special attention is given to the distribution of the ledges and layers best adapted to building purposes, the properties recommending the various kinds of stone and the effects of weathering upon the natural outcrops. Special attention is given to the minute structure of building stone and changes which they undergo in the process of weathering, as revealed by the microscope. This is practically a new field as regards constructional materials, and has never been systematically applied to rocks as building stones. It promises most fruitful and interesting results.

In the report which has already been begun it is intended to give full descriptions of the localities and of the quarries now opened, statistics as to production and the methods of getting out the stone. Illustrations of some of the finer grades of the ornamental varieties and the more important buildings and constructions erected from Missouri stone will also be given.

INQUIRY CONCERNING MINERALS.

Aside from the mineral deposits which are at the present time mined on a commercial scale there exists a large number of other minerals which are not yet taken out in quantities sufficient to be of much value in trade. Facts in regard to these are continually accumulating from all parts of the state. Some of these minerals are known to have a very considerable economic value, and will necessarily soon be the subject of special inquiry. Others will be found to have only a scientific interest. Many having little or no value from an economic standpoint are now attracting popular attention and are causing considerable expenditures of money, time and labor every year, with absolutely no possibility of any adequate returns. On the other hand, a number of those having a great economic value are not being worked to the extent that they deserve, or they have received no notice whatever. Even though many of the minerals in the state should prove to be of no commercial importance, negative results are by no means without value. Proof that certain deposits are not extensive enough, or are not of a sufficiently high grade for profitable working, will be the means of preventing annually a great waste of money and energy.

For the study of these minerals much fine material has been brought together. In their consideration there will be given a complete list of the various kinds, full descriptions of their different occurrences, a catalogue of the known localities of each and the possibilities of their extent and utilization. A careful crystallographic examination will also be undertaken. Since Missouri affords some of the finest samples in the world for this line of inquiry, the subject will prove to be of exceptional interest and value.

SPECIAL LOCAL GEOLOGY.

As already explained, there are particular areas smaller than counties which require detailed mapping in a somewhat different manner than in the case of the county as a whole. These areas are designated as sheets. Since the beginning of the present survey a number of typical areas have been selected as districts demanding this kind of minute mapping. Those in which the work is now practically finished are known as:

1. Lexington Sheet, in Lafayette county.
2. Warrensburg Sheet, in Johnson county.
3. Huntsville Sheet, in Randolph county.
4. Mine LaMotte, in Madison county.
5. Richmond Sheet, in Ray county.
6. Clinton Sheet, in Henry county.
7. Calhoun Sheet, in Henry county.
8. Carthage Sheet, in Jasper county.
9. Joplin Sheet, in Jasper county.
10. Bonne Terre Sheet, in St. Francois county.
11. Bolivar Sheet, in Polk county.
12. Aurora Sheet, in Lawrence county.

The reports accompanying one-half of these sheets were written and revised during the past year, and will soon be ready for publication. They are on the same plan and in the same style as the three sheets completed—the Higginsville, Bevier and Iron Mountain.

MINERAL RESOURCES OF COUNTIES.

In conducting the areal work of the state it is quite probable that with a large part of it the county, instead of the sheet, must be taken as the most convenient unit upon which to report. As the state is the political unit of the nation, so the county is the political unit of the state. When, therefore, in either the larger or the smaller of the two provinces it is desirable to consider any subject with special reference to its areal distribution, the units mentioned become the natural divisions into which a complex topic may be separated. In former years this was universally the practice; in the earlier work the recorded results of all investigations were contained in the county reports. At this time the country was new, and little more was required than to indicate the existence of the various deposits; moreover, much of the energy of the Survey was necessarily directed toward tracing the limits of the different geological formations.

Although it has become of recent years the practice to adopt a smaller and more scientific unit as the basis of areal reports, there nevertheless remain good grounds for retaining the county as the unit in all cases except the most important mining districts. Indeed, the reasons for making the county the areal unit in the treatment of the natural resources of a region are many:

1. It is the most widely known and familiar political division of local importance.
2. It is the district concerning which nearly every person in the state who is interested in the natural products of his neighborhood inquires.
3. It forms a convenient district for working out geological details.
4. It is an area whose size is perhaps best suited to the purposes of instruction in the schools.
5. It is especially adapted to the encouragement of detailed work by local observers.
6. It is the district most commonly inquired about by investigators living in other parts of the state or in different places beyond its limits.
7. In Missouri it is an area well suited to the preparation of maps.
8. It in no way interferes with the adoption of other units of uniform size for a state atlas as occasion demands.

In the beginning of the investigation into natural resources of the state, a general reconnaissance must be made and the subject work pushed somewhat more vigorously than the areal work. This having now been accomplished in great measure, the energies of the survey will be directed toward pressing to rapid completion the now strictly local inquiries and the work which is of more direct benefit to the people at large. It was not possible to accomplish this until after certain preliminary work was taken up. Detailed investigation of a number of counties has already been undertaken where the conditions are especially favorable. Although every county in the state must be thoroughly studied before the completion of the survey, it is readily understood that all of these districts cannot be taken up at once. Some must of necessity be studied before others. In making a beginning in this direction, the work has been governed to a great extent by the investigation as a whole, those regions being taken up first which best furnish an index to the surrounding counties, thus enabling the work to be done over large areas, and in a much shorter time than would otherwise be possible. Another important factor in determining the priority of certain counties in which operations have been begun has been the presence of volunteer and local assistants. In this way some counties containing educational institutions have afforded special facilities. The instructors of geological classes in the several colleges have given, to a greater or less extent, attention to the natural features of the surrounding country, and have often accumulated considerable information. By utilizing the facts previously obtained, and by extending the observations so as to accord with the general plan of the survey, the state comes into possession of material of great practical value at a small cost. The reports of these counties will thus serve not only for purposes of class instruction, but will reach the public much sooner than they would under less favorable circumstances. In this way work has been undertaken in a number of counties, and considerable progress has been made.

The general scheme followed in the discussion of each county includes a brief general account of the surface relief and drainage, a description of the lithological characters of the different rocks and the geological structure of the strata. The principal geological subdivisions are considered separately, and the means of recognizing each pointed out. All the mineral deposits of a useful nature are described, the various localities taken up in detail, the extent and distribution defined and the present and future value noted. The soils and minerals are also discussed, and the discriminations to be made are pointed out. Chemical analyses and practical tests of the various substances are also given. Illustrations are incorporated wherever required. A map on a suitable scale accompanies the report of each county.

SUMMARY OF GENERAL GEOLOGY.

The geological and structural features of Missouri formations have never been discussed on broad lines and in accordance with modern methods. The want of something of this kind has long been felt, and the demands for such information daily becomes more urgent. Of course, an account of this kind cannot be gotten up in a few months, even if all the energies of the survey were directed toward it. It is only acquired as the result of years of labor. Happily, however, the greater part of the information may be obtained as the work on the more directly useful lines is being prosecuted.

All geological investigation, in its accomplishment, demands the settling of certain broad fundamental questions relating to the origin and succession of the formations; and these must be considered in order that the best results may be secured in regard to the more strictly economic work. Some of these problems are wide-reaching in their bearing. They are not confined to a single district, nor a single county, but may extend over a greater part of the state, or through several states. Fortunately, many of these problems had already been partially or wholly solved before the work of the Survey had begun. A general study of the rocks, their arrangement and relations in this and adjoining states, had been made. These results greatly facilitated the preliminary investigations which invariably must precede all detailed examinations. With the broad general questions of interstate importance already tolerably well understood, those which apply more particularly to the state alone are much more easily taken up and more readily solved than they could be otherwise. There is considerable work of this kind yet to be done. A discussion of it, which embraces a somewhat generalized and co-ordinated consideration of the lithological characters of the different formations, the structure and arrangement of the various beds and a classification of the formations in accordance with the latest criteria of geological science, is necessary. The direct bearing of the general geological problems upon the more strictly economic phases of the several topics is shown more in detail in connection with the remarks on the different subjects of which special mention has been made.

Enough facts have already accumulated and sufficient data brought together to enable the general scheme of the final report to be fully outlined. It includes a general description of the geological features and structure of the upper Mississippi valley, particularly as applying to Missouri. It takes up the separate geological formations and describes in detail the characters and distinguishing features of each. It considers the arrangement, succession and thicknesses of the formations, the variability of the different strata, the unconformities and deformations. It notes particularly the useful minerals and substances occurring in the different parts of each formation, and points out how most readily to detect the deposits; it considers also other usefully materials which are not as yet utilized. It discusses further the origin, conditions of deposition, and the associations of the various beds.

It is necessary in this connection to mention only some of the problems of unusual interest. The occurrence and relations of the post-Paleozoic formations in the southeastern corner of the state; the exact limits and relations of the Upper and Lower Coal Measures; the character of the divisional plane at the base of the Coal Measures; the exact position of the lead and zinc-bearing formations on the border of the Ozark uplift; the character of the Devonian in Missouri and its exact equivalents to similar formations of other parts of the Mississippi valley; the subdivisions of the Silurian; the extent and upper limits of the Cambrian rocks—all of these questions are of the utmost import, not only scientifically, but economically.

DICTIONARY OF ELEVATIONS.

As set forth in a former statement, the subject of hypsometry of the state has never received exact investigation. "The elevations of different points in the state are only approximately determined, and the distribution of the zones of equal altitudes are not defined. In connection with mapping, it becomes quite necessary that the relative elevations, at least, of various points in the state which are included within the different areas, should be known with reasonable exactness. The datum to which all such elevations are referred is the "mean sea-level;" and in all cases it is necessary to reduce all assumed altitudes to this standard. The primary base-lines are the lines of precise leveling of the Mississippi and Missouri River Commissions along the respective streams, and the trans-continental line of the U. S. Coast and Geodetic Survey which traverses the state. The secondary base-lines are the lines of leveling for the various railways, where constructed or surveyed throughout the state, as embodied in their profiles or level books. As the methods by which railroad leveling is done are far less exact than the precise leveling of the government surveys, errors in the determinant of altitudes frequently occur, and, in order that their results may be used, the errors must be detected and eliminated. For these purposes, profiles or lists of elevations along all the various railroads have been obtained. These have been compared at their intersections, and any discrepancies which are detected have been inquired into and corrected. As all the various lines are adjusted, a net-work of lines of level throughout the state is found, upon which may be based all mapping." The report, which is now practically completed, contains a corrected list of elevations along all the lines of railroad, and is accompanied by a map on which are indicated the different belts of altitude over all the district. Aside from its invaluable aid in connection with the work of the Survey, it will satisfy a great and ever-increasing demand for information of this character.

Work Prospective.

From the beginning, it has been the policy of the Survey to take up first those subjects which were thought to demand greatest attention, and as far as possible in order of their importance. Aside from these topics, there yet remain a number of themes which as yet have practically remained untouched. With the present resources for conducting the work, it is of course a physical impossibility to carry on all lines of investigation at once. Some must of necessity wait until others have been fully disposed of satisfactorily.

It is unnecessary to call special attention to all of the lines of work which must be taken up before the survey of the natural resources will have been regarded as measurably complete, and a full invoice of the state's possessions and possibilities will have been made known. But there are a few subjects which are urgently requiring early notice.

SOILS.

Of all the states in the Mississippi basin, Missouri is to be particularly benefited by a systematic inquiry into the exact character of the soils. Lying only partly within the drift area, fully one-half of the state's area possesses soils which are directly dependent for their degree of fertility upon the underlying rocks. With this intimate relation between the various strata and the soils into which they graduate, the question assumes an importance that is practically impossible to arrive at in the more northern districts.

Of recent years, there has probably been no phase of geology which has attracted more attention than the study of soils. Owing to the great fertility of the virgin prairies of Missouri, artificial fertilizers have not as yet come into use as in the older states of the Union and in the densely populated countries of Europe. Nevertheless, it has begun to dawn upon many communities, as it must necessarily sooner or later everywhere, that the soils may not yield so abundantly as years go by. In different parts of the country, the real conditions are rapidly being comprehended and efforts being made to rejuvenate the failing soils. The awakening is now occurring in many places, particularly in the eastern and southern states. But the subject is not receiving attention only in those districts where the soils are partly or wholly "worn out." It is beginning to be found out that in many places, even where the soil is surpassingly fertile, proper treatment may greatly increase the yield of the products raised.

Aside from the inherent qualities of the soils, there are certain climatic conditions which need careful noting. More than once during the past two decades have occurred in this and in the neighboring states, in successive years, violent fluctuations in the total yields of the various crops, and at least two or three times within the period the crops have narrowly escaped almost total failure, owing to prolonged droughts. Human efforts are of little avail in attempting to change these varying climatic conditions, but it is quite possible to effect the same results by manipulating the soil so that it will retain sufficient moisture to carry all vegetation safely through the most protracted dry spells. The accomplishment of this is made possible through the proper chemical and physical investigation of the different soils.

Heretofore geology has been almost universally regarded as the sole aid to mining; but of recent years it comes to be considered that it is destined soon to be the chief factor in the advancement of agriculture. The interdependence of the science of geology and the science of agriculture is daily becoming more and more intimate. The relations between the primitive rock ledges and the soils resulting from their disintegration are ever becoming better understood. The principle lying at the base of the more recent soil investigations is that each geological formation gives rise to a more or less well-marked type which is especially adapted to particular crops. The latest work in regard to this subject has been on the physical rather than on the chemical side, and the results have been so eminently satisfactory that it seems desirable to summarize briefly the conclusions deduced from the application of a mechanical analysis of the soils.

In the first place, starting from the fact that the farmer, simply from the character and appearance of the soil, is better able than the chemist, with his most refined analysis, to tell what kind of grain it will produce, there is reason to believe that the differences in the value of the soils is due rather to their texture and the arrangement of grains than to their chemical composition; that all soils contain sufficient food material to support crops for years; and that their value is measured not by chemical composition, but by their relations to the moisture contained.

Moisture in a soil, or the circulation of water in it, is very important, and is believed to be one of the leading determining factors in the local distribution of plants. The circulation of water in the soil is brought about by two forces, gravity and surface tension. The first is constant, and acts always in the one direction, so that it may be practically neglected. The second acts in any direction, either by pulling the water up to the plant or away from it, according to circumstances. Careful investigation and calculation has shown that, upon an average, fifty per cent of the volume of the soil contains no solids, but is made up of only water and air, and may be regarded as empty space. If a soil is slightly moist, the water will form films around the component grains. If there is an increase of water these films will thicken, and, the amount of surface exposed being smaller in proportion to the weight of water, the surface tension will become low. If, however, the amount of water be decreased the surface tension increases, as the surface exposed is much greater in proportion to the less weight of water.

In a cubic foot of soil the total surface exposure of the particles is usually in the neighborhood of 50,000 square feet, or a little more than an acre. In some kinds of soil it is over two acres. This amount of space may be divided in different ways, and the manner in which it is broken up controls largely the surface tension of the soil moisture. In turn, this determines the relation of the soil to the amount of water it will hold. Experiments have shown that different chemicals have two distinct effects upon the soils. One is to directly modify the surface tension of the soil moisture; and the other is to indirectly accomplish the same result by inducing changes in the texture. Since upon the surface tension existing in the soil depends its ability to absorb and to retain moisture, important changes in the capacities of land may be brought about through the application of proper chemicals, and the power of a given soil to resist drought may be very greatly increased.

The importance of this soil work has awakened a special interest in it all over the country, and especially in the eastern states. The Department of Agriculture at Washington has also taken the subject in hand, and has established a special bureau whose energies are to be devoted in this direction. The work in a general way is to be extended over the whole of the national domain. In order, however, that such an investigation of the soils may be made more directly responsive to the needs of Missouri, and the results made available at the earliest possible moment, special work in this direction must be begun by the state at an early day.

ARTESIAN WATERS.

The demand for artesian waters, while not so widespread as in the states north and west, is yet urgent in many parts of Missouri. The desire for this source of water is not because the state is not well supplied with streams at the surface, nor because of unfavorable climatic influences, but by reason of the great convenience in the use of flowing wells, and on account of the common belief that such water is exceptionally pure. With the desire of securing flowing wells, borings have been put down in all parts of the state. In a large number of the cases failure has resulted. Why the efforts are not successful is marvelled at, since the principles involved in a successful artesian flow are so simple that it comes to be generally believed that the governing conditions are equally simple, and all that is necessary is to put down a hole far enough and a flowing well will result. In reality the conditions of a successful flow are quite complex, and the practical determination of artesian areas involves a broad comprehension of the general geological features of the region, not of the state alone, but of the surrounding territory as well.

Although work on this subject has not yet been formally begun, there has, nevertheless, been considerable information obtained indirectly. Records of a large number of borings and deep wells have been secured, and samples of the drillings or cores preserved whenever possible. When the theme is taken up and the work of collecting facts concerning the artesian probabilities for the various portions of the state is pushed vigorously, the data now constantly accumulating will form an invaluable foundation. Moreover, the collection of drill records adds vastly to a knowledge of the characters of the older and more deeply buried formations in Missouri, and discloses much of value in regard to their texture and structural relations.

It is perhaps somewhat premature to give at this time an outline of a report, but the investigation would embrace, among others, the following considerations:

1. A mapping out of the different areas supplying artesian flows.
2. The essential conditions of flowing wells, with special application to the state. The structure of the region, the geographical distribution of the formations, the texture of the rocks, the amount of rainfall, and kindred topics, come under this head.
3. The nature of artesian wells, and questions pertaining to the flow, the force and the factors upon which it is dependent, the height

to which the water rises, causes of decrease in flow and methods of increasing it.

4. The special uses of the waters, such as the adaptabilities of artesian flows, their values as sources of power, as supplies for city water-works, and as medicinal remedies.

5. Methods of boring and special forms of machinery which have been found to be most economical, and a description of these, are within the scope of the work.

6. Particular and unusual conditions of individual areas.

It will be readily seen that fundamental to this work is the careful collection and study of the records of all wells previously sunk in the state. These records become very largely the basis of subsequent work. In the determination of flow levels, certain geological horizons have been found to be water-bearing. For example, the Dakota sandstone is in South Dakota the source of many wells; in northeastern Iowa the St. Peter sandstone is the best known stratum performing a similar function. It becomes important to determine which among the many layers is most likely to prove valuable for this purpose. Next to the question of what horizon may be expected to furnish supplies of water, comes that of the depth at which it will be encountered. This may be made out by a careful comparison of the levels of outcrops, surface waters, horizons in neighboring wells, and similar data. The areas available for artesian wells can, therefore, only be determined by a detailed study of the structure and texture of the rocks, as well as the other conditions mentioned.

ROAD MATERIALS.

Throughout the country the question of bettering the public highways has of recent years been receiving wide-spread attention. While the subject is largely an engineering one, and while a discussion of the advantages and general durability of good roads in the state also comes within the province of other fields, there are, nevertheless, certain phases of the question which properly come within the range of the investigations for which the Survey was organized. Among the things which may be regarded as demanding attention are the localities and character of any superior stone suitable for improving the roads, the facilities for transportation and the approximate cost of quarrying and preparation. In addition, the qualities and properties of these rocks are to be considered. The location of good gravels, their areal extent and their quality should also receive attention. The subject of the utilization of burnt clays as a road material should be fully discussed. Some of the railroads are already using burnt clay for ballast in preference to rock, sand or gravel, with good results, so that the extension of the use of this material to highways is in reality beyond the experimental stage. In this connection, special attention should be paid to the great dump-heaps which are always found at the mouths of coal mines over a considerable area of the state, and which, through spontaneous combustion, afford large quantities of thoroughly burnt clay. The extent to which these dumps might be used for road construction, at practically the cost of hauling the material away, is a matter of no small consequence.

WATER-POWERS.

The water-powers of Missouri appear destined to soon assume an importance previously not thought of. Since the recent great development of and the constant widening of the uses of electricity call for an inquiry for utilizing the energies now going to waste in the rapid streams of the state, especially those in the southern half, the day cannot be far distant when the powers of the water-ways must be converted into a form of energy of the highest practical utility, capable of being transferred great distances with small loss, and of furnishing not only the light, but heat, and the means of running machinery of all kinds. The amount of power that may be brought under control and turned into useful ways from the streams of the state is unquestionably great, and is a problem of the utmost import to every community.

NATURAL GAS AND OIL.

The possibilities of finding natural gas and oil have long occupied the attention of many Missourians. With the recent discovery and extensive use of these substances in the neighboring provinces, the interest in the subject has been renewed and greatly intensified. Indeed, it may be truthfully said, that during the past decade no geological question has occasioned more popular concern than that of the likelihood of obtaining natural gas and petroleum within the limits of the state. In a number of places shallow borings have yielded, from time to time, sufficient quantities of natural gas for local use. The success of these small wells has led to the putting down of much deeper ones, and the expenditure of considerable amounts of money. The excitement awakened by the discovery of oil and gas in Pennsylvania, Ohio and Indiana has stimulated still farther the efforts to secure them in Missouri. The general opinion has been, not only in this state, but in others as well, that the only prerequisite necessary to the securing of a successful flow of natural gas and oil is the sinking of a deep well. In reality the subject is much more complex than is commonly supposed. There are certain natural conditions, all of which must be fully considered before a successful flow of either substance can be obtained. The absence of any one of these can only result in failure. These conditions may be reduced to four categories: There must be (1) a suitable receptacle or reservoir in which the oil and gas may accumulate; (2) a non-porous cover to retain them; (3) a particular geological structure or arrangement of strata, and (4) a pressure sufficient to force the oil and gas to the surface.

So far as is known, the extent to which the satisfying of these conditions, in so far as they pertain to Missouri, is accomplished, may be briefly stated here. The presence in the rocks of Missouri of considerable quantities of petroleum is well known. The occurrences of extensive coarse sandstones, conglomerates and porous limestones, which act as reservoirs, are also known. The existence of compact, impervious shales, which serve as covers for the more porous beds, is well understood. Artesian or hydraulic pressure sufficient to bring to the surface oil or gas, should either exist, is present thoughout most of the state. The remaining condition—that of geological structure—is the chief one which requires investigation in Missouri. The particular phase of geological structure in question is that the rocks must be tilted. This causes in the porous rocks a movement of the water, oil and gas particles, in a simple mechanical rearrangement. They accumulate in order of their specific gravities—the water at the bottom, then the oil, and finally the gas at the top. The special structure of the strata which will accomplish the desired effect is ordinarily known as the arch, fold or anticline. When the top of a fold is pierced gas escapes; when the arch is penetrated a little farther down oil flows out, and when the base of the bow is drilled into, only water appears. The most essential line of investigation that is connected with the inquiry into the probabilities of the occurrence of oil and gas in the state is the determination of the location, extent and trend of the folds.

LIME.

Perhaps no state in the Union is better supplied than Missouri with limestone suitable for the manufacture of a high grade of quicklime. Some localities are furnishing a quality of lime which may be regarded as having no superior in the world. Recent inquiry has shown that the lime industry is not developed nearly to the extent that it might be, and that rocks well adapted to the manufacture of lime are more generally distributed than was supposed. In many places where lime was formerly burned, the industry could now be readily and profitably revived, as the circumstances which formerly militated against its continuance are now largely removed. The subject of lime was one of the first which was taken up for investigation, but owing to circumstances which could not be foreseen, the examination was delayed after the work had fairly begun. Among the topics to be considered in this connection are the properties and qualities of the various limes made in the different localities, the superiority of certain grades, and the chemical and physical characters of the rocks especially adapted to lime manufacture. The components which give value to lime and those which have a deleterious effect are much better understood at the present time than they were formerly; and the grade of lime that can be produced from given lime rocks may now be predicted with considerable accuracy. The methods adopted and the improvements which may be made in the lime industry should receive full consideration. This industry should be one of the most noteworthy in the whole state.

CEMENTS.

With the rapid development of the material prosperity of the state, cements come to have a greater and greater importance each year. The term itself has recently come to be used in a much broader sense than formerly, and now applies to all those calcined lime products which will set or harden under water. Those grades which are capable of a more or less complete hardening are commonly called hydraulic limes, and are generally considered better than the ordinary varieties. Aside from the so-called hydraulic limestones which occur in various parts of the state, there are doubtless other materials which are capable of being made into a high grade of Portland or hydraulic cement. The investigations should determine the extent of the deposits, their composition and the methods of preparation.

DRIFT DEPOSITS.

Although a systematic examination of the unconsolidated deposits lying above bed-rock in the northern half of the state was begun, the removal of the person in charge to a distant locality, beyond the limits of the state, led to the temporary abandonment of the investigation. The work outlined consists of a reconnoissance to determine the general character, relations and geographical distribution of the various Pleistocene deposits. It will lay the foundation for a part of the study of the soils and road materials, and will further have an important incidental bearing upon other economic questions.

MINOR TOPICS.

Among the minor deposits which should be eventually investigated thoroughly are a number of more or less wide interest.

Substances suitable for the manufacture of mineral paints are of more than local import.

The sands for glass-making and other purposes require careful discrimination. Glass-making has already become an important industry in the state, and the deposits should be accurately delineated.

Marls for fertilizing purposes may in the future form valuable acquisitions to the mineral wealth of the state, though they may not be used at present. The extent and location of the deposits should be made known.

CABINET.

The collections made during the pursuit of the various lines of investigation are always divided into two classes. One group is composed entirely of specimens obtained for the purpose of study or analysis; the other group is made up of specimens for exhibition in the cabinet. Heretofore the latter has received comparatively little attention, partly for reason, perhaps, of the insufficient room to properly display them. It is expected that in the future much more time may be devoted to this branch of the work. The progress of the survey is now far enough along to enable this to be done in a highly creditable manner, provided the requisite amount of display space is obtained. In connection with the different lines of inquiry, there accumulates a large quantity of valuable material which illustrates in an admirable way the natural products of the state. The best and most typical of these are brought together, carefully labeled and deposited in the rooms set aside for them. It is expected ultimately that all of the mineral materials found in each county will be fully represented, and the collection will form a complete index of what may be obtained in the state. Being attractively displayed and conveniently placed, architects, engineers and others may readily and easily examine and compare the various samples, and learn what is best adapted for their respective purposes. The cabinet serves to show in the best manner possible what Missouri possesses. There are represented the various ores, clays, building-stones, soils, limes, coals, minerals, fuels and innumerable other things of interest, as well as the products made from various raw materials. A series of photographs is also being prepared to illustrate the various geological phenomena, and, incidentally, Missouri scenery. A set of charts is in preparation showing the distribution and structure of the various useful deposits. The models already referred to in connection with mapping are also designed to be made useful in this connection.

The material for the cabinet which has been obtained by different members of the Survey is added to by the co-operation of many individuals. Owners of various quarries have thus offered to furnish, suitably dressed, different samples of building and ornamental stones. Proprietors of clay industries have been liberal in supplying suites of their wares and the raw materials. Operators have endeavored to send in representative sets of their mine products; others have likewise aided. Although this work has only been fairly started, the ensuing years will show great gains.

In extending the usefulness of the work of the Survey, special attention is now being paid to the selection of an educational series of specimens illustrative of the mineral resources of the state. As might naturally be expected, in connection with the minerals for the cabinet, there necessarily accumulates many duplicates which are not needed by the Survey after they have been studied and reported upon. Most of this material is of the greatest value for class instruction in colleges and high schools, and may be made available for this purpose at little or no additional expense to the Survey. A number of educational institutions have already expressed their desire to obtain suites illustrative of the geology and economic resources of the state. In the case of the State University, installments of this kind have already been selected and made ready. Additional collections will follow shortly, and other institutions provided for in order of their applications.

As a further aid in college instruction, and as a special means of familiarizing the students with geological phenomena of Missouri, a selected set of photographs pertaining to Missouri geology has been arranged for, and may be disposed of at the nominal cost of making the prints. This series will be added to continually, and will be made more and more complete as the work of the Survey goes on. A printed list of these photographs, which may now be had, will be printed shortly, together with an explanation of the phenomena they represent. From this catalogue each instructor will be able to choose those photographs he most desires.

LIBRARY.

No special effort has been made to form a complete library. However, through exchanges and gifts from scientific institutions, a nucleus of a geological library has been established. It is essentially a working collection of books, and is designed to serve as a reference library for those directly interested in the geology of the State. Several hundred books bearing directly upon geology, besides many others incidentally referring to geological themes have been secured. In addition, a considerable number of pamphlets and unbound volumes have been acquired. At the present time these are in the geological rooms. Efforts are being made to make the collection as complete as possible in the literature pertaining directly to the local geology of the State, and in the publications which, though relating to the geology of other states, throw light on the geological structure and resources of Missouri.

In this connection there is in preparation a complete bibliography of the literature relating to the geology of the state. It is in the form of a dictionary catalogue, with abundant cross-references.

PUBLICATIONS OF THE SURVEY.

A full explanation has already been made of the general plan adopted in the reports of the Survey. In placing the results of the various investigations before the public, progress was necessarily apparently slow. The reasons are obvious. Now that the survey is under good head-way, the reports on the various lines of work taken up will appear in more rapid succession than heretofore. Altogether there have been printed in the various reports about 3000 pages, of which over one-half have been issued during the past eight months; and during the same period nearly as much additional manuscript has been revised and made ready for printing.

Briefly, the contents of the reports are appended.

BULLETINS.

470 Pages, 13 Plates, 11 Figures.

CONTENTS:

No. 1. Administrative Report; Coal Beds of Lafayette County; Building Stone and Clays of Iron, St. Francois and Madison Counties; Preliminary Catalogue of Fossils Occurring in Missouri.

No. 2. Bibliography of Geology of Missouri.

No. 3. Clay, Stone, Lime and Sand Industries of St. Louis City and County; Mineral waters of Henry, St. Clair, Johnson and Benton Counties.

No. 4. Description of Lower Carboniferous Crinoids of Missouri.

No. 5. Age and Origin of the Crystalline Rocks of Missouri; Clays and Building Stones of Certain Western-Central Counties Tributary to Kansas City.

SHEET REPORTS.

204 Pages, 11 Plates, 23 Figures.

CONTENTS:

No. 1. Higginsville Sheet, Lafayette county: Topography, hydography, soils, forestry, stratigraphic and structural geology, coal, building stones and clays.

No. 2. Bevier Sheet, including portions of Macon, Randolph and Chariton counties.

No. 3. Iron Mountain Sheet, including portions of Iron, St. Francois and Madison counties.

BIENNIAL REPORTS.

150 Pages, 5 Plates, 1 Diagram.

CONTENTS:

1. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines, to the Thirty-sixth General Assembly.
2. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines, to the Thirty-seventh General Assembly.
3. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines to the Thirty-eighth General Assembly.

VOLUME I. PRELIMINARY REPORT ON COAL.

BY ARTHUR WINSLOW.

227 Pages, 1 Plate, 131 Figures.

CONTENTS:

Chapter I. Coal Measures.
Chapter II. Coal Beds.
Chapter III. Coal Industry.
Chapter IV. Systematic Description of Coal Beds.
Appendix A. Coal Mining in Thin Beds.
Appendix B. Coal Operators of Missouri.

VOLUME II. IRON ORES.

BY FRANK L. NASON.

366 Pages, 9 Plates, 62 Figures.

CONTENTS:

Chapter I. Ores of Iron.
Chapter II. Iron Ores of Missouri.
Chapter III. Specular Ores of the Porphyry Region.
Chapter IV. Red Hematites of Missouri.
Chapter V. General Geology of the Ozark Uplift.
Chapter VI. Specular Ore of Sandstone Region.
Chapter VII. Limonite Ores.
Chapter VIII. Introduction to Iron Ore Localities.
Chapter IX. Specular Ores in Sandstone.
Chapter X. Limonites.
Chapter XI. Red Hematites.
Appendix A. Iron Ore Deposits of Northeastern Arkansas.
Appendix B. Historical and Statistical Sketch of Iron Industry.

VOLUME III. MINERAL WATERS.

BY PAUL SCHWEITZER.

256 Pages, 34 Plates, 11 Figures.

CONTENTS:

Chapter I. Origin of Mineral Waters.
Chapter II. Analysis and Composition of Mineral Waters.
Chapter III. Therapeutics of Mineral Waters.
Chapter IV. Mineral Waters of the State.
Chapter V. Muriatic Waters or Brines.
Chapter VI. Alkaline Waters.

Chapter VII. Sulphatic Waters.
Chapter VIII. Chalybeate Waters.
Chapter IX. Sulphur Waters.
Chapter X. European and Missouri Waters Compared.
Appendix A. Relations between Grains per Litre and Grains per Gallon.
Appendix B. Additional Analysis of Missouri Mineral Waters.
Appendix C. Bibliography of Mineral Waters.

VOLUME IV. PALEONTOLOGY (PART I).

BY CHARLES ROLLIN KEYES.

314 Pages, 34 Plates, 9 Figures.

CONTENTS:

Chapter I. Introduction.
Chapter II. Sketch of Missouri Stratigraphy.
Chapter III. Biological Relations of Fossils.
Chapter IV. Protozoans and Sponges.
Chapter V. Hydrozoids and Corals.
Chapter VI. Echinoderms: Echinoids and Asteroids.
Chapter VII. Echinoderms: Cystids and Blastoids.
Chapter VIII. Echinoderms: Crinoids.
Chapter IX. Worms and Crustaceans.
Appendix. Stratigraphic Catalogue of Missouri Fossils.

VOLUME V. PALEONTOLOGY (PART II).

BY CHARLES ROLLIN KEYES.

320 Pages, 22 Plates, 2 Figures.

CONTENTS:

Chapter X. Polyzoans.
Chapter XI. Brachiopods.
Chapter XII. Lamellibranchs.
Chapter XIII. Gasteropods.
Chapter XIV. Cephalopods.
Chapter XV. Vertebrates.
Appendix. Synonymic Indexical List of Fossils of Missouri.

VOLUME VI. LEAD AND ZINC DEPOSITS (SECTION I).

BY ARTHUR WINSLOW.

387 Pages, 12 Plates, 71 Figures.

CONTENTS:

Chapter I. Historical Sketch of Lead and Zinc.
Chapter II. Lead and Zinc and their Compounds.
Chapter III. Distribution and Conditions of Occurrence of Lead and Zinc.
Chapter IV. Lead and Zinc Deposits of Foreign Countries.
Chapter V. Lead and Zinc Deposits of the United States.
Chapter VI. Industry and Statistics of Lead and Zinc.
Chapter VII. History of Mining in Missouri.
Chapter VIII. Physiography of the Mining Districts.
Chapter IX. General Geology.

VOLUME VII. LEAD AND ZINC DEPOSITS (SECTION II).

BY ARTHUR WINSLOW.

401 Pages, 28 Plates, 196 Figures.

CONTENTS:

Chapter X. General Geology.
Chapter XI. Geological History of Southern Missouri.
Chapter XII. Ore Deposits.
Chapter XIII. Industry and Statistics of Lead and Zinc.
Chapter XIV. Mines of the Southwestern District.
Chapter XV. Mines of the Southeastern District.
Chapter XVI. Mines of the Central District.
Appendix A. Study of Cherts of Missouri, by E. O. Hovey.
Appendix B. Methods of Analysis, by J. D. Robertson.
Appendix C. List of References.

VOLUME VIII. ANNUAL REPORT. (READY)

BY CHARLES ROLLIN KEYES.

400 Pages, 25 Plates, 20 Figures.

CONTENTS (accompanying papers):

Biennial Report of the State Geologist.
Coal Measures of Missouri, by G. C. Broadhead.
Crystalline Rocks, by Erasmus Haworth.
Tables of Altitudes in Missouri, by C. F. Marbut
Fundamental Characteristics of the Ozark Mountains.

INDIVIDUAL WORK OF THE GEOLOGICAL CORPS.

During the past year the efforts of the Survey have been restricted in regard to the field work somewhat more than in previous years. The energies of the different members of the geological corps have therefore been directed largely toward bringing together some of the results obtained during several years of investigation, finishing up this work so they could be published, and in preparing for the press other information secured. The necessary field work has been undertaken for completing the reports on the several subjects begun in previous years.

In addition to the administrative duties connected with the Survey, and the editing and supervision of the printing of the reports, the State Geologist has personally undertaken to complete the investigation of the building stones of the state, the work of which has progressed as rapidly as circumstances would permit. A general account of the geology of the state has also been begun, but this must necessarily go on slowly at first. Besides, numerous short field examinations have been taken in order to settle disputed or doubtful points which have come up in the course of the work in different parts of the state. The report on Paleontology was finished and published. Several minor papers were also prepared for different scientific journals.

Mr. E. H. Lonsdale, who was formerly connected with the Survey, but who has for the past year and a half been engaged in geological work in a neighboring state, has recently resumed work in Missouri. He is thoroughly familiar with the investigations being carried on, and the details of the various lines of work in progress. As a special theme of investigation, he has undertaken an inquiry concerning certain building materials of the state, and it is presumed that a report embodying the results of this work will form one of the most instructive reports to appear, and at the same time one of great practical value.

Dr. Erasmus Haworth has recently given considerable time to a full and a final revision of his report on the crystalline rocks of Missouri. This is a very interesting piece of work, and one which has long been needed, for practically nothing has been written regarding the economic value of the granites of Missouri. The rock has proved to be a good grade of stone for all kinds of building and ornamental purposes. Moreover, it has no equal in the Mississippi valley, and is destined to have far wider utilization than at the present time, though some of the finest buildings in the large cities have been constructed of it, in part at least. The study of these rocks was begun some ten years ago at private expense. Afterward, it was continued in connection with the Federal survey. Subsequently, the investigations were taken up under the auspices of the Missouri survey. The original plan was therefore changed somewhat, and the work adapted to the special needs of the people of the State. This report is now practically ready, and will form a part of volume VIII.

Prof. H. A. Wheeler has continued his investigations and experiments upon the clays of the state. The field work is completed, the physical tests finished and the chemical analyses made. The report is already more than half written, and the entire manuscript promises to be ready for printing by the first of June next. The wealth of Missouri in clays for nearly all purposes is something astonishing, as brought out by the recent study. The discovery of extensive deposits of good china clays will certainly attract capital sufficient to start up on an extensive scale a new industry for the state.

Mr. C. F. Marbut, who has had charge of the detailed mapping for some time, has pushed the work with vigor. During the past summer he has finished several of the sheets previously begun. Before the close of the season all the work assigned to him was completed in a thoroughly satisfactory manner. During and since his completion of the field work on the several areas, Mr. Marbut has written full accounts of the geology, and these reports, by the time the drawings for the illustrations are prepared, will be ready for the press. The demand for these sheets has become urgent, and it is hoped that no unnecessary delays will occur to prevent an early publication of these reports. Further, a report of the hypsometry, or the altitudes of the state, upon which Mr. Marbut has been engaged as part of his work for the past four years, is finished, and forms a part of volume VIII. It will be essentially a dictionary of elevations of all the towns and principal points in the entire state. All errors and discrepancies have been carefully eliminated so far as possible, and all altitudes reduced to mean sea-level as a datum plane.

Mr. Arthur Winslow has been engaged chiefly in bringing together materials for his report on the lead and zinc deposits, first as an officer of the Survey and later by contract. This work was begun several years ago, and notes gathered and observations made without serious interruptions during that period. In July of the present year the manuscript of the report was finally completed and the printing begun. For the succeeding five months the final revision of the work was carried on, and the proofs read as the matter went through the press; two bulky volumes of some 800 pages, illustrated by suitable cuts and maps, are the outcome of these reports.

Mr. J. D. Robertson was in the employ of the Survey during the first half of the present biennial period. His efforts were directed largely in assisting on the lead and zinc report.

Prof. E. M. Shepard, who for several years past has been engaged upon the areal geology of the region around Springfield, has recently submitted a detailed account of his observations, which will be incorporated in a very full report on the district. It forms a valuable contribution to the geology of the southwestern part of the state, and it is hoped that the printing of the report may be begun early in the spring.

Prof. J. E. Todd, who has spent several summers in making a study of the drift or superficial deposits of the state, has commenced the preparation of a report on the subject, with the assurance that it will be ready for submission early in the summer.

CO-OPERATION OF FEDERAL AND STATE SURVEYS.

An effort has been made recently to obtain aid from the United States Geological Survey, on work which is too expensive for the state organization to undertake satisfactorily without greatly increasing its facilities, yet it is work which is very necessary as a fundamental help to the determination of the economic resources of a district. As a result, the director of the Federal Survey has expressed a willingness to co-operate in certain lines of work, and it is expected that a party will be put in the field during the coming season. The plan has worked well in other states, and it is believed that Missouri will be greatly benefited by the aid thus received.

EXPENDITURES DURING THE BIENNIAL PERIOD.

During the past biennial period the appropriation for the continuance of the Survey was only one-half as much as it was during previous terms. A tabulated statement showing the distribution of the funds is given below.

Salaries	$9,329 07
Subsistence	464 20
Railway fares	535 22
Horse and wagon hire	263 45
Postage and telegrams	179 53
Freight and express	475 14
Office furniture	80 95
Office instruments	76 85
Office supplies	157 58
Cabinet supplies	6 80
Laboratory instruments	7 48
Laboratory supplies	133 23
Field instruments	1 70
Field supplies	4 93
Library, books	96 37
Photographs and supplies	103 74
Reports, printing	3,415 82
Reports, binding	168 00
Maps	757 55
Plates	420 46
Figures, drawing, etc	131 43
Office printing	86 19
Temporary assistance	361 35
Special assistance	2,741 86
Balance	1 10
	$20,000 00

FUTURE OPERATIONS OF THE GEOLOGICAL SURVEY.

PRESENT STATUS OF THE WORK.

In continuing the geological survey of Missouri, profit should be derived from the work of the past, and careful attention paid to the experience gained. In the previous pages there have been briefly outlined the scope of the survey and methods followed in investigating the natural resources of the state. A summary is also given of what has already been accomplished, of the work which is now in progress, and of the work which yet remains to be taken up. It may be readily inferred that a geological survey of a region, a thorough investigation of the useful deposits of a given district, is not something which a state may well do without, but in reality is one of the fundamental factors in all industrial activities.

The demands for information and aid which are continually being made upon the Survey from nearly every part of the state, show clearly the widespread interest taken in the different lines of investigation with which it has to deal. As the work continues, the fact is becoming more and more generally recognized by the people that the class of investigations now being carried on is what should have been undertaken and completed long ago. The work of the geological survey is now fairly begun. The plans of operation are progressing systematically. The results are rapidly accumulating. In order that the work may be carried to completion, time is required. Any delay, back-set or suspension of the work can only give rise to a depreciation, in a great measure, of the results already secured. That the attainments may last for all time to the benefit of the State, liberal provision is necessary to carry the work to completion.

RECAPITULATION.

To summarize briefly, the work finished during the past biennial period, as shown by the published results, has been the report on paleontology, in two parts; the lead and zinc report, also in two parts—four volumes in all; and two sheet reports—the Iron Mountain and the Bevier. The work on ten other sheets has been in great part finished, and the report on crystalline rocks and several minor subjects have been made ready for printing. The investigation of the clays and building stones and the mapping of certain areas have made good progress.

Of the work demanding immediate attention, there are the reports which are practically complete and now regarded as ready for publication. These are five sheet reports on areas in the central and western parts of the state, which were prepared during the past summer, the reports on the granite rocks of the southeast, the dictionary of elevations, and the memoir on the formations of the Coal Measures. Besides, there are several important reports which are very nearly ready, some requiring a little field work, others needing some further preparation and revision before being sent to the press. Among these may be mentioned two sheets in the southeastern part of the state, four sheets and Greene county, in the southwest, and the report on clays of all the state.

There are several lines of work which are far enough along to be completed during the next two years; these are the examination of the building stones and the geology of several districts. As new work, the examinations of all useful minerals of the state, and of building materials, should be commenced at an early date.

CONTINUATION OF THE INVESTIGATIONS.

Previous estimates made for conducting the operations of the geological survey have been based on $40,000 for the biennial term, and during the first three years the amount made available was at this rate. During the next biennial period there will be, in addition to the continuation of the regular work and the accomplishment of the necessary field operations, a large amount of material which must be prepared for printing; and this last feature will form a much heavier item of expense than heretofore, for the reason that results have been allowed to accumulate. Nevertheless, it is believed that the work is now so far advanced that it may be carried on successfully and satisfactorily on $14,500 annually, or $29,000 for the biennial term. This amount is considerably less than what has been counted on in former years. Of course a larger amount would enable the work to go on just so much faster, and permit the results to be brought out more rapidly. But it is believed that with a moderate outlay, even though the work be extended somewhat, it can be conducted more economically, and in reality more speedily, than if a larger sum were expended one term, and in the next, perhaps, a much smaller one.

DISTRIBUTION OF REPORTS.

The printing of the reports is naturally the heaviest item of expense connected with the survey, and ordinarily should use up fully one-half of the available resources. This expenditure may be in great measure overcome by modifying the present way of distributing the reports. After supplying the reports to the members of the legislature, state officers, state institutions, college and school libraries and leading newspapers of the state, and persons giving aid to the Survey, first-class libraries and geologists of national reputation beyond the limits of the state, and a small number to satisfy future demands and exchanges, all remaining volumes may be sold at the cost price of each volume, the moneys thus accruing to be covered back into the treasury of the state. By this method of distribution, from one-half to two-thirds of the total amount of printing would, in the course of a decade, revert to the treasury. The selling price per volume would never be more than one dollar, and often only one-half of this—an amount sufficient to prevent undue wasting. Reports would get into hands where they would do the most good to the state. The distribution could be more properly and more equitably made. The geological reports have an intrinsic value, and under the present method of disposition command good prices at the book dealers, as the editions are exhausted.

Even the old Swallow report of 1855 now sells for $2.50 or $3. The Pampelly report and atlas of 1872 readily brings $8; and the Broadhead report of 1874, $5. These facts are mentioned merely in order to show how the reports of the geological survey are regarded by those living not only inside of the state, but far beyond the borders as well. Furthermore, similar scientific reports of other states, and of nearly every civilized country issuing publications of this kind, are held for sale, usually at cost. The geological reports of the neighboring states of Arkansas, Iowa and Minnesota are thus sold; and the scientific memoirs issued by the Federal government are distributed in a similar manner.